Arizona Drought Preparedness Plan

BACKGROUND
& IMPACT ASSESSMENT
SECTION

Governor's Drought Task Force

Governor Janet Napolitano

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BACKGROUND SECTION

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Executive Summary

Arizona has been affected by drought conditions during most of the last decade. It is not known at this time whether the drought conditions will abate in the short term, or whether this is a multi-decade drought sequence as has occurred in the past. However, it is absolutely clear that this is not the last drought that will affect the state. The economic and environmental impacts of drought continue to increase as the population of the state increases. Recent conditions on the Colorado River have initiated critical discussion that some had thought were long-range issues, with water levels in Lake Mead and Lake Powell at the lowest level since the dams were built. Although Arizona has a reliable water supply by comparison to several of its neighboring states, drought conditions in the rural parts of Arizona have had devastating personal and economic impacts. In addition, due to the Central Arizona Project's low priority on the Colorado River system, there is cause for some concern about the ability of the existing system to respond to long-term drought that affects both the Colorado and the Salt-Verde system. Arizona has made huge investments in importing and storing water supplies for the major metropolitan areas, and those investments have significantly buffered the state from impacts during the current drought. However, there is a need for further preparedness in case conditions worsen.

On March 20, 2003 Governor Janet Napolitano issued Executive Order 2003-12 and established the Governor's Drought Task Force to address the drought issues facing all Arizonans further directing the Arizona Department of Water Resources to provide leadership in this effort.

The goal of the Arizona Drought Preparedness Plan is to:

1. Identify the impacts of drought to the various sectors of water uses;

2. Define the sources of drought vulnerability for water use sectors and outline monitoring programs to alert water users and resource managers of the onset and severity of drought events; and

3. Prepare drought response options and drought mitigation strategies to reduce the impact of drought to water users in Arizona.

To achieve these goals, State leaders have developed a "plan" that will be reviewed annually and if necessary updated to provide the most up to date information and technology to not only prepare for drought but to provide the tools necessary that can be implemented to reduce the impacts from drought. The information in the Arizona Drought Preparedness Plan will assist State leaders, in concert with water users, planners, and resource managers, prepare for and respond to current and future drought conditions in Arizona. The Arizona Drought Preparedness Plan consists of two components:

1. Background and Impact Assessment – defines drought in Arizona, provides an historical context of drought, and catalogues the historical impacts and sources of drought vulnerability of water use sectors and water supplies, and
2. Operational Drought Plan – identifies regional vulnerability to drought impacts, identifies drought response options, defines drought mitigation strategies, outlines monitoring activities and programs to alert water users and

resource managers of the onset of drought, and provides an implementation plan to respond to drought events.

The intent of this portion of the Arizona Drought Preparedness Plan - Background and Impact Assessment – is to provide information necessary to understand the dynamic climate conditions that effect Arizona and what role drought has in that dynamic. Further, Arizona has a complex set of water laws that influence water planning in this state. A description of these laws is provided herein. Finally, the Task Force was focused on maximizing to every extent possible, stakeholder input and involvement. As such, a committee was created to develop a comprehensive monitoring network and drought trigger levels to provide early warning for the citizens of this state. Additionally impact assessment workgroups were establish for the following sectors to identify impacts and vulnerabilities and to identify potential mitigation and response options. The culmination of these efforts are contained in the Workgroup Reports that can be found in the Appendices of this document that provide extensive insight into drought and its impacts.

Chapter 1 - Introduction

Arizona has been affected by drought conditions for six out of the last seven years, and virtually all parts of the state have a cumulative water supply deficit. Concern regarding the impacts of drought reached a peak in 2002, which was one of the driest years in the last century. Until recently, the major urban areas of Arizona, Phoenix and Tucson, were thought to be 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 Central Arizona Project. In addition, Arizona has made major investments in managing the groundwater supplies in the Active Management Areas of the state (Phoenix, Tucson, Pinal, Prescott and Santa Cruz, see Figure 1, below). However, recent serious drought conditions and new information about drought patterns in the last 1000 years based on tree-ring analysis, have raised awareness of the need for a comprehensive state drought plan and ways to address the possibility of long-term, sustained drought conditions.

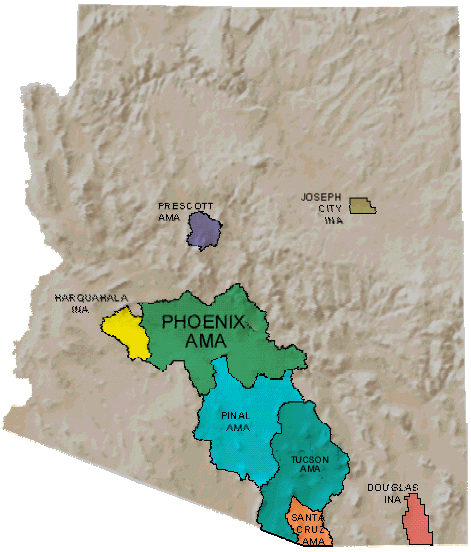

Figure 1: Active Management Areas within Arizona

The most urgent need is in the growing communities in the rural parts of the state, where alternative water supplies are generally very limited and the economy is strongly affected by drought (particularly grazing, recreation, and forestry-related sectors). Some of the most significant effects of the drought are environmental—multiple aquatic species are at risk, and wildfires and bark beetles are decimating woodlands and forests of Arizona. The environmental impacts of drought are generally more difficult to manage than the societal impacts.

Drought is cumulative, and does not affect all economic sectors in the same ways. This plan 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.

A. Executive Order

Governor Janet Napolitano established the Governor's Drought Task Force by executive order on March 20, 2003 (see Appendix I, Executive Order 2003-12). Drought response activities in Arizona were previously handled within the Department of Emergency Management, but recognizing the differences between drought and other types of emergencies and the need for proactive drought planning, the Governor directed the Department of Water Resources to provide leadership in this effort.

The Executive Order required the development of three major products: a short-term drought plan for the summer of 2003 that was adopted on July 10, 2003 (see Appendix II, Potable Water Plan); a long-term drought mitigation and coordination plan to address various specified areas of concern (represented by this document); and development and

implementation of a statewide water conservation strategy, which will be submitted to the Governor separately but at the same time as this Plan.

The Drought Task Force itself is comprised of state agencies and elected officials (see Appendix III, Drought Task Force Membership). However, broad public and stakeholder participation has been encouraged. Workgroups have been established to actively solicit input from the municipal and industrial sectors, irrigated agriculture, environmental and resource management interests, tribal governments, and the commerce, recreation and tourism sector. In addition, public and private sector volunteers who provided valuable expertise directly supported the planning process.[1] Additionally, over 1,000 people have been regularly notified of the Task Force's activities and meetings as well a series of seven public workshops prior to release of this draft plan. Furthermore, public input will continue to be encouraged as the plan is implemented. The Task Force has also been aided by experts from the National Drought Mitigation Center and supported financially by the US Department of the Interior, Bureau of Reclamation.

B. Approach/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
- 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 has been a key objective from the beginning of this effort. Developing a plan that quickly becomes obsolete and does not adapt to changing conditions will not make a contribution to the long-term welfare of the state, while an adaptive program that focuses on building institutional and stakeholder relationships and an improved information base over time should prove more robust in responding effectively to changing conditions.

The Drought Task Force has developed a planning process that encourages the use of the latest scientific information, particularly in enhancing the use of climate forecasts and monitoring data at the regional scale to enhance the utility of drought-related information for decision-makers. In addition to the strong science focus, the process has been designed to maximize stakeholder input, especially in monitoring conditions locally across the state and helping to shape the communication and response processes. 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.

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[1] Among the entities that have donated staff time to drafting this document are the Salt River Project, the University of Arizona, the Central Arizona Project, the Bureau of Reclamation, the cities of Phoenix and Scottsdale, the Agri-Business Council, Project WET, and numerous private firms: Arizona-American Water Company, HDR Engineers, Hargis and Associates, and Malcolm Pirnie.

This effort has also focused on defining the conditions that create vulnerability to drought in each sector and identifying potential adaptive responses. This is intended to increase the effectiveness of drought planning and reduce long-term costs related to emergencies.

Capacity building is an essential component of the proposed process. Implementation is focused at the local level, and will encourage local responses to local conditions and concerns. In this way, the plan recognizes the strengths inherent in local knowledge about conditions, practices, and values, while providing a comprehensive statewide support structure to help communities and impacted sectors better prepare for drought in the future.

C. Drought Definitions

For purposes of the Arizona Drought Preparedness Plan a definition of drought was developed to provide the basis needed to guide the development of appropriate triggers and monitoring activities. ***Drought, in this context is defined as a sustained, natural reduction in precipitation that results in negative impacts to the environment and human activities.*** Although drought is a natural, recurring feature of climate, occurring in high as well as low rainfall areas, drought is more than just a moisture deficit. Beyond the definition of drought is the magnitude of the impacts on the environment and to human activities. The extent of drought impacts is dependent on multiple physical and social factors, including several climate variables, water use patterns and vulnerability. Drought affects various sectors of society in different ways, and can be defined in many ways- thus perception is an important element in qualitatively gauging the impact of drought. The risk associated with drought for any region is a product of both the region's exposure to the event (i.e. probability of occurrence at various severity levels) and the vulnerability of society (and the environment) to the event. Subsequent droughts in the same region will have different effects, even if they are identical in intensity and spatial characteristics, because societal (and ecological) characteristics will have changed (National Drought Mitigation Center). Following are other key definitions that will be used in the Arizona Drought Preparedness Plan.

For monitoring purposes the following definitions will be used. ***Indicators*** are variables to describe drought conditions (examples - precipitation, stream flow, groundwater, reservoir levels, soil moisture, etc.). The indicators have been identified for each Climate Division, identified in the following section and will allow the monitoring committee to assess data against historic data to determine if a trigger has been tripped. ***Triggers*** are specific values of each indicator that initiate and terminate each drought status level, and subsequent suggested management responses. Additionally, drought will be described using timescale that relate to the observed climatic impacts. ***Short-term Drought*** is measured by the departure of precipitation or another drought indicator from average conditions on a time-scale from one to several months. ***Long-term Drought*** is measured when sustained precipitation deficits over time periods of one to several years affect surface and subsurface water supplies.

After each stage of drought has been identified, certain actions will need to be initiated. The Governor's Drought Task Force has focused on water users taking necessary actions to respond to drought or in reducing the impacts that may occur at each stage. Impacts are

the visible results of the effects of drought. ***Impacts*** vary across the state based on climatic and social activities and are the economic, social, and environmental effects that occur, either directly or indirectly, as a result of drought. Each workgroup has identified individual impacts for each water-using sector within the state. ***Vulnerability*** refers to the level of risk of an area, water supply, or water user for suffering negative consequences as a result of the temporary or permanent reduction in a water supply as a direct result of drought. ***Mitigation*** is pre-drought actions or programs that reduce risk and impacts and enhance recovery. ***Response*** is an action implemented as a result of drought that is short-term and is aimed at reducing impacts and enhancing recovery. More general definitions are contained in Appendix IV of this document.

D. Evaluating Drought in Multiple Sectors and Locations

The Arizona Drought Plan acknowledges that drought affects multiple sectors in the same location differently, and establishes trigger mechanisms that are related to the vulnerability of each 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, 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 triggers also acknowledge and work in concert with the relatively complex institutional water management context.

The drought indices, monitoring techniques and trigger points will continue to be further refined in the future to respond to the varied landscape types in Arizona's primary physiographic regions (basin and range, Mogollon Rim, Colorado plateau) and the influence of local and regional elevation-induced weather and climate patterns. The Arizona Drought Preparedness Plan will be reviewed on an annual basis and modified as improvements are made in the process.

Chapter 2 - Background

A coordinated response to drought requires an understanding of the local and regional economic and environmental sectors that are vulnerable to drought. An understanding of drought and the associated impacts can guide drought response planning and drought mitigation plans. The purpose of this chapter is to:

- Summarize the Arizona's climate and historical context of drought events in Arizona;
- Summarize Arizona's definition of drought used for long-term drought planning;
- Identify sectors of Arizona's economy and environment impacted by drought and the potential impacts of drought events to each sector with additional emphasis on drought impacts to forests and the relationship with wild land fire;
- Define potential impacts of simultaneous drought events on the Colorado River system and the Salt River system;
- Identify planning and institutional sensitivities in long-term drought planning in Arizona; and
- Summarize jurisdictional and institutional issues related to drought planning.

A. Arizona Climate Summary

Arizona's climate is considered to be arid under "normal" conditions, and much of the state is classified as desert. As is typical of most of the world's desert regions, Arizona's climate is strongly influenced by subtropical atmospheric circulation. However, the interplay of subtropical high pressure features with mid-latitude circulation, such as the polar and subtropical jet streams during the winter, and with the North American monsoon circulation during summer, determines the season-to-season (intraseasonal) and year-to-year (interannual) variations in precipitation, sunshine, and temperature.

Precipitation in Arizona is highly seasonal, with peaks during the winter (November-April) and summer (July-September). The summer precipitation peak is most pronounced in southeastern Arizona, and generally becomes more pronounced as one proceeds from west to east across the state. Winter precipitation is associated with widespread storms, one to several days in duration, which provide rains at lower elevations and snowfall at higher elevations. Winter precipitation is particularly important to Arizona water supply, as cooler winter temperatures attenuate evaporation in the soil and surface water bodies, and allow snowpack to persist until the spring. In contrast, summer precipitation is associated with convective thunderstorm activity accompanying the North American monsoon circulation; summer precipitation is typically high intensity, short duration, and spatially heterogeneous. Because summer precipitation is high intensity and is accompanied by maximum annual temperatures and high rates of evapotranspiration, recharge to the soil column and water supplies is limited during the summer.

In addition to strong seasonality, Arizona precipitation, like that of most of the world's desert regions, is characterized by a high degree of year-to-year (interannual) variation. One of the key factors influencing interannual precipitation variations in Arizona, during winter in particular, is the El Niño-Southern Oscillation, a multi-season to multi-year variation in equatorial Pacific Ocean temperatures and associated atmospheric circulation.

El Niño-Southern Oscillation has varied considerably in frequency, intensity, and interval between El Niño and La Niña phase over the historical and paleoclimate record.

When El Niño-Southern Oscillation is in its El Niño phase, Arizona frequently receives above average winter precipitation, due to an enhanced subtropical jet stream and increased low-latitude moisture available to storms tracking across the Southwest. However, the El Niño-wet Arizona winter connection is quite variable, and although most of the wettest Arizona winters have occurred during the El Niño phase, there have been a considerable number of dry Arizona El Niño winters. When El Niño-Southern Oscillation is in its La Niña phase, Arizona is most frequently dry, and is reliably not wet, due to a more northern storm track and increased influence of subtropical high pressure. During, the past two decades, several La Niña episodes (e.g., 1989-90, 1995-96, 1998-2001) have initiated Arizona droughts.

Paleoclimate research indicates a strong connection between the historical frequency and intensity of the La Niña phase and multi-year drought in the Southwest. The noted 1950's drought, which had exceedingly severe effects on New Mexico and the Southern Plains states (and to a somewhat lesser extent, Arizona), was embedded during a longer-term 1940s-1970s dry period in Arizona, associated with more frequent La Niñas and fewer and lower magnitude El Niños. A so-called *step change* in Pacific Basin climate in 1976-77 heralded two decades of wet conditions in the Southwest, associated with more frequent and higher magnitude El Niños.

Multi-decade time scale changes in the climate of both the Pacific and Atlantic Ocean basins are implicated in severe sustained drought in Arizona. In the Pacific Ocean, a feature called the Pacific Decadal Oscillation has been associated with the record of winter (November-March) precipitation variations in the western United States. The major multi-year Arizona droughts of the past 110 years, late 1800s-early 1900s, 1950s, 1996-present, occurred during negative phases of the Pacific Decadal Oscillation. Sea surface temperatures and western U.S. drought patterns since 1999 indicate the possibility that the Pacific Decadal Oscillation might have shifted to a phase favoring dry conditions in Arizona for the next ~20 years. Research indicates that, across Arizona, 1999-2003 is one of the driest 5-year periods of winter precipitation in the instrumental climate record. Concern about an episode of Pacific Decadal Oscillation-influenced prolonged drought in Arizona is heightened by the fact that the long-term predictability of winter precipitation in the Southwest is diminished during dry Southwest Pacific Decadal Oscillation phases.

The multi-decadal behavior of the Atlantic Ocean has also been associated with multi-decade dry conditions in the Southwest. The Atlantic Multidecadal Oscillation in conjunction with Pacific Ocean climate patterns, such as El Niño-Southern Oscillation, appears to produce atmospheric circulation patterns conducive to enhanced La Nina-like conditions in the Southwest.

The paleoclimate record of drought shows that the late 1500s is probably the drought of record in Arizona for the last 1000 years. This drought has been tied to record low flows on the Colorado River, native population collapse due to disease in Mexico, as well as widespread drought conditions across North America. Reconstructions of Arizona climate division winter (November-April) precipitation show extensive dry periods in some or all parts of Arizona during virtually every century in the last 1000 years, with notable multi-

year droughts in the mid-1200s, late 1500s, mid-to-late 1600s, mid-1700s, late 1800s, early 1900s, and mid-20th century. Most of the aforementioned winter dry periods were more severe and many more sustained than the Arizona drought of the last 5-8 years.

B. Defining Drought

Drought has been described as an "insidious natural disaster." A drought is a climatic event that can extend for single season or last for several years. Typically, the onset and cessation of drought is difficult to gauge until after the episode. Droughts are difficult to predict and their level of intensity is often related to pre-existing conditions. For example, drought conditions following a wet season may not be as severe as a similar magnitude drought that follows a normal or subnormal run-off year.

A long-term drought can have devastating impacts to nearly all sectors of a local or regional economy and environment. For example, in Texas, the 1996 drought caused $1.9 billion in losses to farmers and cattle-growers and removed $5 billion from the Texas economy.

A drought may impact individual sectors of the economy or environment differently, due to differences in vulnerability and location. The definition of the drought for the operational plan will consider differences in drought impacts by sector, degree of vulnerability, and location. The conceptual definition of drought is as follows:

"Drought is a sustained natural reduction in precipitation that results in negative impacts to the environment and human activities. The National Drought Mitigation Center defines four basic types of drought: 1) Meteorological or climatological; 2) Agricultural; 3) Hydrological, and 4) Socioeconomic.

- Meteorological or climatological drought is defined in terms of the magnitude of a precipitation shortfall and the duration of this shortfall event.
- Agricultural drought links the various characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, and soil moisture deficit.
- Hydrological droughts are characterized by periods of precipitation shortfall that result in an effect on surface or subsurface water supply, rather than direct impacts of precipitation shortfalls. Hydrological droughts are typically out of phase or lag the occurrence of meteorological and agricultural drought. Where irrigation is necessary for agriculture, agricultural drought is really determined by hydrological drought.
- Socioeconomic drought associates the supply and demand of some economic good with elements of meteorological, agricultural, and hydrological drought."

In Arizona, drought is more than just a moisture deficit. It is the result of a complex interplay between water uses, both cultural and natural uses, and natural precipitation that operates on varying time and spatial levels. The extent of drought reflects local and regional geography, climate variables, water use patterns, water supply vulnerability, and cultural preferences. The extent of the impact to a particular sector and/or region is

an important element in qualitatively gauging the impact of drought. Therefore, local perceptions are a fundamental component of defining the level of drought impact.

C. Economic and Environmental Sectors Impacted by Drought

Drought impacts broad areas of Arizona's economy and environment. Through research, investigation, and public involvement, the Governor's Drought Task Force identified the following sectors of Arizona's economy and environment that are vulnerable to impacts from drought events:

- Irrigated Agriculture
- Municipal and Industrial Water Users
- Energy Production
- Public Health
- Wildlife
- Environmental Health and Watershed Management
- Livestock
- Commerce and Recreation
- Tourism

The economic and environmental sectors and potential impacts are identified in Table 1.

TABLE 1. Economic and Environmental Sectors and Potential Drought Impacts

Sector	***Potential Drought Impacts***
Irrigated Agriculture	Reduction in soil moisture, Reduced crop quality, Reduced crop yields, Increased pest outbreaks, Increased water supply costs, Increased management applications (fertilizer, herbicides, pesticides),
Municipal and Industrial Water Users	Increased water demands due reduction to precipitation, Reduced water supplies (groundwater and surface water), Economic impacts from reduced water sales or production,
Energy Production	Reduced hydroelectric production, Increased power demands due to increased temperatures and agricultural uses, Reduction in water supply available for cooling water,
Public Health	Population stress, Potential reduction in water quality, Increased potential of disease transmission,
Environmental Health and Watershed Management	Increased frequency and severity of forest fires, Pest outbreaks (e.g. Bark beetles), Reduction in watershed production, Reduction in habitat quality and forage production, Potential for increased erosion/arroyo formation,
Livestock and Wildlife	Reduced water supply, Increased mortality,

	Reduced recruitment, Increased supplemental feed costs, Increased predation, Reductions in herd size, Increased potential for disease outbreaks, Increased potential for human-wildlife contact
Commerce and Recreation	Reduced sales and use of outdoor recreation equipment, Reduction in rural recreation economy, Decreased water related recreation, Reduction in in-migration of new businesses, Potential increased migration from rural areas to urban areas, including international migration,
Tourism	Reduced visitations to parks, Decreased number of winter visitors, Decrease in conventions and hospitality events.

Each sector has differing vulnerabilities to the impacts of drought. Within each sector, vulnerability to drought may vary regionally. A sector's vulnerability to drought is generally a function of the reliability of the available water supply, availability of replacement or backup water supplies, and the degree of impact that occurs from a reduction in supply. For example, an irrigated farm may experience different impacts than a neighboring ranch operation experiencing the same drought. The farm may have the option of drilling a well to replace some or all of the reduced supply to save a portion of the crop. The ranch may not have the option of developing groundwater and may have to reduce the herd size or sell off the stock entirely. Furthermore, different types of drought (e.g. meteorological, agricultural, hydrologic, and socioeconomic) can trigger different impact to the sectors at different times. For example, municipal water providers may experience increased water demands during a meteorological drought because lack of precipitation causes customers to water their lawns more frequently. If a drought deepens, the same water provider may experience a hydrologic drought if a reduction in water supply (e.g. reduced reservoir storage) occurs. Finally, in an extended drought, the water provider may endure a socioeconomic drought, if the revenue of the entity is reduced due to decreased water deliveries or sales.

The paleoclimatic history of Arizona records several important drought events and related impacts. Perhaps the most dramatic is the potential association of extended drought events in the mid-1200's and 1400's with the abandonment of settlements across the southwest. In recent memory, the drought of the 1950's and early 1960's had far reaching impacts to Arizona's economy and environment. Rural surface water supplies were reduced due to the drought. In response, new groundwater resources were rapidly developed, particularly for mining and municipal uses in rural Arizona. The reduction of water supplies on the Salt and Verde Rivers caused additional groundwater development in central Arizona. The drought had political impacts as well. The drought illustrated the vulnerability of surface water supplies in Central Arizona. As a result, the drought galvanized political support for development of the Central Arizona Project.

D. Impact To Arizona Forests And Wildland Fire

The major factors affecting fire frequency, size, and intensity include the following: the nature and dynamics of the ecosystem (including history of past fires), land management practices, sources of ignition, and climate and weather (including drought). These factors have interacted in complex ways during the last two centuries to produce the conditions that currently bear on Arizona's landscape and fire ecology.

The story of drought's multiple roles in shaping Arizona's landscape and fire ecology requires a brief examination of some of the aforementioned factors and how they have varied over time. A highly simplified history of the effects of land management on fire ecology, based on a combination of tree-ring and instrumental fire history records, shows that Arizona low- and mid-elevation forests (~6000-8000 feet) were subject to relatively frequent low intensity surface fires prior to European settlement[2]. Fires were more frequent in low elevation forests and fire frequency decreased as moist conditions increased with elevation. With the introduction of logging, many large stem trees were removed from Arizona forests (in particular, Ponderosa pine forests). Historic livestock grazing and fire suppression promoted the development of dense stands of younger, thin-stemmed trees, commonly known as "dog hair thickets." This condition now threatens Arizona forests, especially the remaining large trees, through competition, possibly easier spread of mortality through disease and insect vectors, and by fueling increasingly extensive high intensity crown fires[3].

Historical sources of fire ignition have typically included natural ignitions from lightning and fires set by Native Americans before European settlement. In recent years, human ignitions have increased, especially during the pre-monsoon season, due in part to population increases, increased use of forests by recreationalists, runaway campfires set by migrants, and arson. In addition to the effects of the aforementioned land management practices on forest stand density, fire spread is now enhanced by the introduction of invasive species, such as some exotic grasses. Moreover, the development of homes in the wildland-urban interface, as well as in formerly isolated forested rural locations, increases the vulnerability of Arizonans to fire.

Drought serves as a catalyst for fire in Arizona. The susceptibility of Arizona grasslands and forests to fire is mediated, in part, by individual dry years and by persistent drought. Tree-ring studies show that the largest pre-1900 fire years were all characterized by significantly below average Palmer Drought Severity Index (PDSI) values[4]. In the modern period, this relationship still holds true. However, regional-scale fire events often occurred a year or two after a wet year or years. This wet/dry cycle indicates that wet seasons and years are important in developing sufficient fine fuels (understory vegetation) to generate a regional fire event[5]. Some of the largest fires in pre-historic and recent

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[2] Swetnam, T.W., and C.H. Baisan, 1996. Historical fire regime patterns in the southwestern United States since AD 1700. In C. D. Allen, editor, Fire effects in southwestern forests, Proceedings of the Second La Mesa Fire Symposium, March 29-31, 1994, Los Alamos, New Mexico. U.S. Department of Agriculture U.S. Forest Service General Technical Report RM-GTR-286. 216 pp.

[3] Allen, Craig D., Melissa Savage, Donald A. Falk, Kieran F. Suckling, Thomas W. Swetnam, Todd Schulke, Peter B. Stacey, Penelope Morgan, Martos Hoffman, and Jon T. Klingel, 2002. Ecological Restoration Of Southwestern Ponderosa Pine Ecosystems: A Broad Perspective. Ecological Applications, Vol. 12, No. 5, pp. 1418–1433.

[4] Swetnam and Baisan, 1996

[5] Swetnam and Baisan, 1996

records were synchronized by this combination of extreme multi-year shifts from moist to drought conditions. Thus, drought synchronizes regional-scale fire.

Drought episodes can cause major changes to the age structure and species composition of forests. The 1950's drought and associated bark beetle outbreaks killed large numbers of trees in the ponderosa forests and pinyon-juniper woodlands of the Colorado Plateau, Mogollon Rim, and Sky Islands of southern Arizona. Many of these dead trees persist as logs and snags (standing dead trees) within these forests and woodlands today. An unusual wet spell occurred in the Southwest from approximately 1976-1993 (with some dry seasons and years during this period), and many tree seedlings, grasses and herbaceous plants established within Arizona forests and woodlands during this period[6]. This new plant growth probably resulted in increased competition among plants for water (and stress) during the ensuing drought. The new plant growth also provided additional fuels for rapid spread and high intensity of wildfire during the past decade.

In summary, drought plays multiple roles in creating conditions that promote fire in Arizona. Persistent drought can stress trees, reduce resistance to insect outbreaks and pathogens, and over time cause directly and indirectly forest mortality and changes in the composition and structure of forests. Drought reduces fuel moisture, and persistent drought can substantially reduce the moisture of large, heavy dead and live fuels; thus drought serves as a catalyst to fire. Finally, the switch of climatic conditions from relatively moist to extremely dry (i.e., drought) over the course of several years results in the synchronization of regional-scale fire across the Southwest during drought years.

E. Potential Impact of Simultaneous Drought Episodes on the Salt and Colorado River Systems

A major concern in drought planning is assessing the drought vulnerability for water providers. Central Arizona encompasses water providers in Maricopa, Pinal, and Pima counties who serve approximately 4,000,000 or 80% of Arizona's population in 2000. Water providers in Maricopa County serve approximately 3,000,000 people. Central Arizona is unique in that it relies on the conjunctive management of two renewable water supply systems (the Central Arizona Project and the Salt River Project), as well as enormous amounts of groundwater in storage. Most water providers and water users in central Arizona rely on one or both of the renewable water supply sources as well as significant amounts of groundwater. A fundamental question in drought planning is what is the potential impact of a simultaneous drought on the Colorado River and Salt River system on water providers in central Arizona.

The degree of impact from a simultaneous sustained drought on water providers in central Arizona is a complex issue. There have been overlapping drought events on the Colorado River and Salt River systems. However, the Salt River Project system is more vulnerable to drought impacts. The Salt River Project has a smaller drainage area (13,000 square miles) and smaller storage capacity (4,000,000 acre-feet) than the Colorado River system water delivered through the Central Arizona Project (242,000 square miles and over 60,000,000 acre-feet of storage). The history of water deliveries shows the difference in

[6] Swetnam, T.W., and J. Betancourt, 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11:3128-3147.

vulnerability between the two systems. There are extended periods, such as the present drought, and the 1950's drought when Salt River Project water deliveries have been reduced due to insufficient storage in the system reservoirs. In contrast, to date, there have been no instances of delivery curtailments on the Colorado River system due to insufficient water supply. However, if the current drought continues, there may shortage declarations on the Colorado River by 2007, which would impact Central Arizona Project water deliveries.

The potential impact from a simultaneous sustained drought on both the Salt and Colorado River systems, assuming that drought was extensive and sustained enough to cause shortage declarations on the Colorado system, are estimated to include the following:

- Reduction in water available for irrigated agriculture
    - CAP delivers approximately 500,000 acre-feet for agricultural water uses, which could be curtailed, including Indian and non-Indian uses,
    - SRP would likely reduce deliveries to its agriculture customers,
- Potential Reduction in water available for SRP municipal customers,
    - Historically, CAP has delivered 800,000 acre-feet of water to SRP to protect SRP customers from shortage,
- Increase in groundwater pumping,
    - SRP would increase reliance on its well fields to make up reduced surface water available for its deliveries,
    - CAP in cooperation with the AWBA would recover water stored to protect CAP M&I customers from shortage,
    - Municipal water providers would also increase groundwater pumping to make up any shortages from SRP or CAP deliveries,

It should be noted that the foregoing impacts, while significant, require both systems to be in a sustained drought at the same time for an extended period. It is unclear from the instrument record or paleoclimate record if such a sustained event would occur at times when reservoir levels were already at low levels. In addition, the availability of significant volumes of groundwater in storage in central Arizona, both as recharge credits and native groundwater could serve to mitigate the impacts of the reduced surface water supply. However, the development and delivery of new water supplies or recovery of stored credits would likely increase water costs during and after the drought event significantly.

F. Planning and Institutional Sensitivities to Long-Term Drought Planning

As stated previously drought impacts vary by sector and region. The role of Arizona's state government in planning for drought events and assisting those impacted by drought may be limited by planning and institutional constraints.

At the planning level, long-term planning is constrained by a lack of long-term data. The ability to define the appropriate thresholds and triggers for drought declaration and actions requires significant data at the local level. The current quality of available data may limit the ability to adequately forecast droughts or to predict impacts with sufficient advanced warning to prevent or mitigate the impacts. The drought plan will consider the monitoring and data gathering network necessary to provide adequate data for

planning. At present the type and density of instruments to measure key drought indicators is not sufficient to predict drought or the impacts that may result.

The ultimate goal of the drought plan will be to develop mitigation plans to prevent drought events from producing impacts. Potential mitigation strategies require a change from the status quo and will cross over from technical analysis to political and institutional impacts. As such, the potential mitigation strategies will need to be developed through coordination with local jurisdictions and stakeholders. The coordinated effort would build consensus proposals that fit the local experience and need. As present, the current plan is constrained to conceptual level mitigation strategies. The potential mitigation strategies may require the development of:

- Alternative water supplies,
- Additional water storage,
- Different land management strategies,
- Increased conservation and drought awareness,
- State mandates for conservation and response, and
- Funding mechanisms to support drought planning and mitigation.

Finally, the current role of the State in long-term drought planning is to provide the information and tools to assist local jurisdictions in responding to drought events. The plan does not contemplate change to the existing regulatory structure or authority. However, to develop mitigation strategies, a change from the status quo is necessary. Such changes to the existing regulatory structure could be considered in the future as mitigation strategies are developed. Future changes might include items such as extending the assured water rules to water providers outside of the Active Management Areas and imposing mandatory water conservation requirements. If these changes are contemplated, they would need to be developed through a stakeholder participation process to build a consensus proposal.

G. Jurisdictional and Institutional Issues

As described above, climate, geology, and topography influence where and how water is used in Arizona. However, jurisdictional and institutional constraints also play an important role in the management of these supplies. Land ownership in Arizona is comprised of private, Tribal, Federal and State lands. Jurisdiction over how water and lands are managed is often outside of the State's authority, and inevitably left to the Courts to decide. Federal lands account for over 60 percent of Arizona, including tribal lands. The Arizona State Land Department also accounts for nearly nine million acres in Arizona, however, state land is not considered to be a public entity, rather it is land which has been set aside to be leased whereby the monies are be used to benefit public education in Arizona. These three agencies control approximately 20 percent (Forest Service), 16 percent (Bureau of Land Management), and 13percent (Arizona State Land Department) of all land in Arizona, respectively. Indian reservations also account for 27percent of lands in Arizona while the remaining 24 percent is split between individual/corporate owners (17%) and other public lands (7%)[7]. Thus, incorporating the Federal Government

[7] (National Agricultural Statistics Service 2002)

and Tribal Government in planning is essential to the success of drought management in this state.

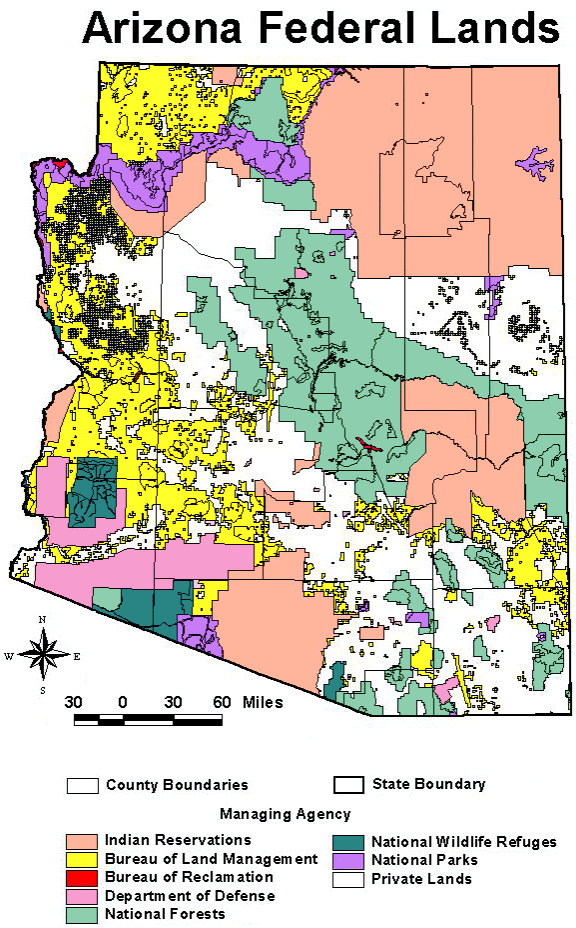

Figure 2: Federal Lands in Arizona

Water laws have been developed to address specific issues that have arisen throughout Arizona's (and Western) history. The Federal government, based on a system of interstate compacts, international treaties, and Supreme Court Decisions, manages Colorado River supplies. Surface water law (other than the Colorado River) is based on historic diversions, giving the oldest water uses (regardless of what the water is used for) priority in times of shortage (Doctrine of Prior Appropriation: first in time, first in right). Groundwater is considered a public water supply but is only vigorously managed in central Arizona in the state's five Active Management Areas. Even under this management framework, historic groundwater uses were "grandfathered" in perpetuity. Outside of the Active Management Areas, groundwater use is not managed except for requiring a permit to drill a well. This existing framework further limits addressing statewide water management.

Chapter 3 – Overview of Water Supplies in Arizona

Although an arid state, Arizona has a diverse array of water resources. These water resources are composed primarily of surface water from rivers and streams, groundwater in underground aquifers, and effluent or reclaimed water. The availability of these resources is constrained by four main factors:

1. Physical availability of the resource – Is there enough "wet" water to meet users needs?
2. Water quality – Is the water chemistry compatible with water users' needs?
3. Water rights and institutional barriers – Do water users have legal access to the resource ("paper" water)?
4. Infrastructure – Do water users have sufficient infrastructure necessary to efficiently use the water supplies?.

The distribution of Arizona's water resources across the state reflects the impact of local and regional precipitation patterns, geology, and geography. These factors generally divide the state into three water resource regions, each with unique water resource characteristics. The three regions are: the Colorado Plateau, the Mogollon Highlands, and the Basin and Range. The distribution of water resources in each region reflects these factors. The physical availability and water quality of water resources is discussed in later sections of the report.

Superimposed on each region are water rights and institutional barriers that may limit the availability of water resources regionally or locally. These limitations may include prior appropriation of available water through water rights decrees or ongoing litigation through water rights adjudications, water use management practices and regulations, endangered species concerns, and environmental considerations. These factors and limitations are discussed more fully in the following section.

In addition, local infrastructure constraints may further limit the ability of a community or individual user to make full use of a water supply. Discussion of individual water users' infrastructure constraints is beyond the scope of the current study. The description of the water rights and institutional barriers is discussed in detail in this section.

A. Colorado River Water

The Colorado River runs approximately 1,400 miles from Colorado's Rocky Mountains to the Sea of Cortez in Mexico. The Colorado River Basin drains approximately 242,000 square miles of land and supplies water to two countries (Mexico and the United States), seven western states (Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada and California), and numerous Indian Tribes. Water from the Colorado River is diverted for many uses including agricultural, potable water supplies for cities and towns, industrial, and environmental. Early in the 20thcentury it was recognized that as these competing demands increased, it was necessary to develop a structure that would provide a long-term secure water supply for its many users.

The development of Colorado River water law includes a long and sometimes contentious history. This is described in the "Law of the River", which includes Congressional acts,

international treaties and Supreme Court decisions. For the most part Western Water Law recognizes users that developed water supplies from rivers through the Doctrine of Prior Appropriation – "first in time, first in right." However, concerns emerged in the upper reaches of the Colorado River Basin as significant development occurred in California and when the U.S. Supreme Court upheld the Doctrine of Prior Appropriation for rivers that crossed multiple States regardless of State boundaries in Wyoming v. Colorado, June 5, 1922, 259 U.S. 419. In southern California, agricultural development in the Imperial Valley began to rely more and more on the Colorado River. However, the River was a unreliable supply during the critical growing season. In 1905, an abnormally high spring runoff resulted in the destruction of small earthen dams that had been constructed to divert Colorado River water to the Imperial Valley. The course of the River changed, flooding the Valley and increasing the size of the Salton Sea from 22 to 500 square miles[8]. The river flowed into the Valley for 16 months before it was returned to its original course. In that time, it destroyed homes and crops and heavily damaged highways, railroads, and irrigation works. This event was a major catalyst to control and regulate the River, including construction of Hoover Dam and the All American Canal

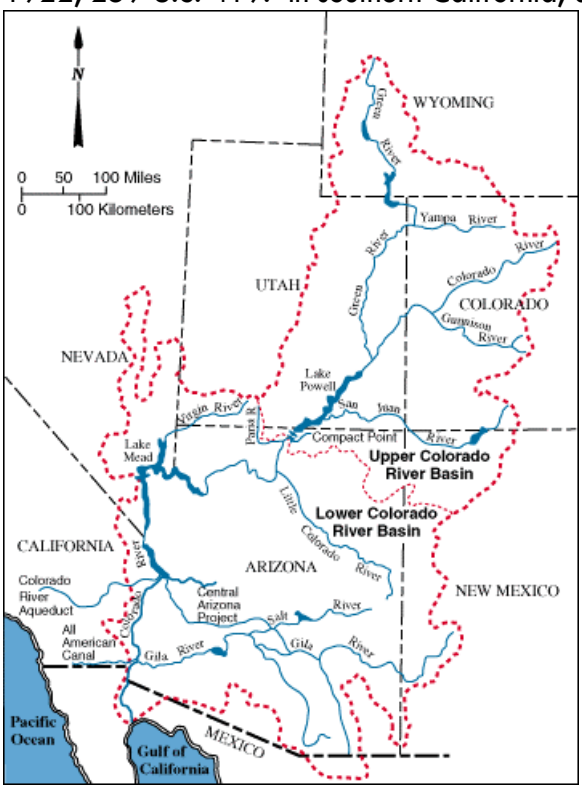

Figure 3: Colorado River Basin
Source: US Bureau of Reclamation

1) Colorado River Compact – 1922

In light of these growing concerns, with the consent of the U.S. Congress in 1921, the seven Colorado River Basin states authorized the appointment of commissioners to negotiate a compact for the apportionment of the water supply of the Colorado River. Although the States were unable to negotiate an allocation of water for each of the States, an agreement was negotiated and signed by the seven appointed commissioners from each of the Colorado River Basin states in November 1922.

The Colorado River Compact (Compact) divided the Colorado River Basin (see Figure 3) into the Upper Basin and the Lower Basin, which are defined as those states or parts of states from which water naturally drains into the Colorado River above and below Lee Ferry, respectively. Lee Ferry is a point on the mainstream of the Colorado River approximately one mile below the mouth of the Paria River in northern Arizona and is

[8] The Salton Sea is a sub-sea level lake in the low desert of southern California, located in the historic floodplain of the Colorado River. In the last one thousand years the River's course has been altered at least three times due to high flows, moving the River's flow to a western channel and forming a freshwater lake called Lake Cahuilla. Eventually, the River would return to its more easterly channel leaving the lake to evaporate.

defined in the Compact as the dividing point between the Upper Basin and the Lower Basin[9].

The Colorado River Compact was successful in apportioning to the Upper Basin (Colorado, New Mexico, Utah, and a portion of Arizona) and to the Lower Basin (Arizona, California, and Nevada) the exclusive beneficial consumptive use of 7.5 million acre-feet of water to each basin annually. Because the Colorado River Basin includes a portion of Mexico, this Compact recognized the right of Mexico to the use of water from the River, however, water for this purpose was to be met from the surplus of water over and above the amounts apportioned to the Upper and Lower Basins. Additionally, any burden that might arise because of a water treaty with Mexico was to be shared equally by the two basins. This Compact recognized that the ability of the Upper basin to meet the requirement to deliver 7.5 million acre-feet to the Lower Basin could be impacted by climatic factors, therefore the Upper Basin is only required to restrict its use so that the flow of the river at Lee Ferry would not be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years. The Compact also recognized existing users in stating in Article VIII of the Compact, "Present perfected rights to the beneficial use of waters of the Colorado River system are unimpaired by this compact."

Although all the commissioners from each of the States signed the agreement, the agreement stated that Congress could not ratify the Colorado River Compact until the State Legislatures of each of the signatory States approved it. The Arizona Legislature was the only State that did not approve the Compact, which resulted in a modification to the Compact that allowed for six-state approval and consent of the U.S. Congress, discussed below in the Boulder Canyon Project Act.

2) Boulder Canyon Project Act - 1928

The Boulder Canyon Project Act (Project Act) authorized construction of the Hoover Dam and Power Plant and the All-American Canal. In addition, it also authorized Arizona, California and Nevada to enter into an agreement whereby the 7.5 million acre-feet of water apportioned to the Lower Basin by the Colorado River Compact would be apportioned as follows: to California, 4.4 million acre-feet per year; to Arizona, 2.8 million acre-feet per year; and to Nevada, 0.3 million acre-feet per year. The three states, however, were unable to agree on the apportionment. .

The provisions of the Project Act stipulated that it would take effect upon fulfillment of either of two conditions. The first was that all seven states ratify the Colorado River Compact. Because Arizona was not satisfied with the terms of the Compact, it became impossible to meet this condition. In fact, Arizona did not ratify the Compact until 1944. The second condition required that six of the states, including California, ratify the Compact, and that California agree to limit its consumptive use of water from the Colorado River to 4.4 million acre-feet, plus one-half of any surplus. With the exception of Arizona, all of the Colorado River Basin states ratified the Compact, and passage of the California Limitation Act in 1929[10] completed the conditions required to make the Project Act effective. President Herbert Hoover declared the Project Act effective, by proclamation, on June 25, 1929.

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[9] Lee Ferry, the dividing point between the Upper and Lower Basins is not the same as Lee's Ferry, an historic river crossing point located 1.3 miles upstream from the dividing point. (The CAP 1918 – 1968, Rich Johnson)

[10] The California Limitation Act addressed the requirement for the consent of the US Congress to six-state approval of the Compact

3) Lower Basin State Agreements and Water Delivery Contracts 1931 – 1944

In 1931, entities within California entered into the California Seven-Party Agreement, at the request of the Secretary of the Interior, to identify priorities among the major water users in the State, prior to entering into water delivery contracts with the users. In 1942 and 1944, the Secretary of the Interior also entered into water delivery contracts with the State of Nevada for 300,000 acre-feet. At this time, the U.S. and Mexico were negotiating an international treaty for a yet unspecified volume of water raising concerns in Arizona about its own entitlement[11]. As a result, Arizona not only entered into a contract with the Secretary for storage and delivery of Colorado River water for 2.8 million acre-feet, but as a part of this contract finally ratified the Colorado River Compact of 1922.

4) Mexican Treaty – 1945

In 1945, a treaty between the United States and Mexico involving waters of the Colorado, Rio Grande and Tijuana Rivers was enacted to address, among other things, a fixed entitlement for Mexico of 1.5 million acre-feet annually from the Colorado River. The Treaty also provided an additional 200,000 acre-feet in years of supply surplus (for a total of 1.7 million acre-feet). In years of extraordinary drought, Mexico's entitlement is to be reduced in the same proportion as consumptive uses in the U.S. are reduced.

The 1945 Treaty dealt with the volumetric entitlement to Mexico, however, it was silent on the quality of that water to be delivered. In 1962, the government of Mexico formally protested to the United States government regarding the quality of Colorado River water that was being delivered to the Mexicali Valley. After 1962, numerous meetings and negotiations led to adoption of Minute 242, executed in 1973, which obligates the United States to implement measures that will maintain the salinity of the Colorado River waters delivered to Mexico at nearly the same quality as that diverted at Imperial Dam for use within the United States. On June 24, 1974, the Colorado River Basin Salinity Control Act was signed into law, providing for the physical works necessary to implement Minute 242 without permanent loss of water to the Colorado River Basin states.

5) Upper Colorado River Basin Compact - 1948

The Upper Colorado River Basin Compact divided the water apportioned to the Upper Basin by the Colorado River Compact between the five states with territory in the Upper Basin. Arizona was allocated 50,000 acre-feet per year with the remainder of the Upper Basin entitlement divided according to the following percentages: Colorado, 51.75; New Mexico, 11.25; Utah, 23.00; and Wyoming, 14.00.

6) Colorado River Storage Project – 1956

In 1956, Congress authorized the Secretary to construct, operate, and maintain the following projects in the Upper Basin, including dams, reservoirs, power plants, transmission facilities, and appurtenant works:

1) Curecanti – consisting of three dams and reservoirs on the Gunnison River in Colorado: Blue Mesa, Morrow Point, and Crystal;
2) Flaming Gorge – located on the Green River on the Wyoming-Utah border;

[11] The CAP 1918 – 1968, R. Johnson p. 19

3) Navajo (dam and reservoir only) – located on the San Juan River in New Mexico; and
4) Glen Canyon – located on the mainstream of the Colorado River on the Utah-Arizona border.

7) *Arizona v. California* - 1964

On August 13, 1952, the State of Arizona filed a complaint with the U.S. Supreme Court against California and seven agencies within that State to resolve the contention by California that the Central Arizona Project should not be authorized because Arizona did not have enough entitlement from the Colorado River to make this project feasible. At California's insistence, the U.S. Congress would not authorize the Central Arizona Project until Arizona's right to the necessary Colorado River entitlement was clarified. California contended that Arizona's access and utilization of water from the rivers located within the State of Arizona (specifically, the Gila River, a tributary of the Colorado River) reduced the amount of water that Arizona should be able to divert from the Colorado. Conversely, Arizona contended that the Colorado River Compact gave Arizona the right to use its tributaries in addition to the 2.8 million acre-feet of Colorado River entitlement. In the complaint, Arizona alleged, that its entitlement to Colorado River water was adversely affected by California and that its existing and prospective projects were threatened.

The Decree, handed down in 1964, confirmed that Congress had already apportioned, through the Boulder Canyon Project Act, the entitlement of water to the three Lower Basin states as follows: Arizona, 2.8 million acre-feet; California, 4.4 million acre-feet; and Nevada, 300,000 acre-feet. Any surplus above 7.5 million acre-feet was apportioned 50 percent to California and 50 percent to Arizona, except that Nevada was given the right to contract for 4 percent of the excess, which would come out of Arizona's share. The Decree also confirmed each of the Lower Basin State's entitlements to the flow of the tributaries within their boundaries, supporting Arizona's utilization of water from its in-State rivers, separate from its entitlement to its full 2.8 million acre-feet of Colorado River water.

The Decree also addressed the division of water in times of shortage stating, "In the event that there is insufficient mainstream water available for release then the Secretary, after providing for satisfaction of present perfected rights[12] in order of their priority dates (regardless of state lines) and after consultation with the parties to major delivery contracts may apportion any remaining water available for consumptive use consistent with the Boulder Canyon Project Act." In its Opinion, the Court dismissed sharing of shortages through equitable apportionment or by the law of prior appropriation stating that, "The Secretary should be free to choose among the recognized methods of apportionment or devise a reasonable method of his own[13]." The approach to sharing of shortages was amended later as a result of the Colorado River Basin Project Act, which gave present perfected rights, users served under contracts, and Federal reservations priority over the Central Arizona Project.

8) Colorado River Basin Project Act - 1968

[12] See Attachment V for listing of present perfected rights
[13] Updating the Hoover Dam Documents

In 1947, Arizona Senators Robert McFarland and Carl Hayden introduced Senate Bill 1175 to authorize the Central Arizona Project, the first of many attempts by Arizona to construct a canal from the Colorado River to Central Arizona. After the decision in *Arizona v. California* and five years of negotiation President Lyndon Johnson signed the Colorado River Basin Project Act on September 30, 1968 authorizing construction of the Central Arizona Project in addition to other water development projects in the Upper Basin. In order to get a Bill passed, several concessions were made on the part of Arizona. A significant concession was a provision that allowed existing California, Arizona, and Nevada Colorado River Contractors to receive a priority over the Central Arizona Project in times when the useable supply from the River was inadequate to provide 7.5 million acre-feet to the Lower Basin States, with California's priority limited to its 4.4 million acre-foot entitlement. The lack of a State Groundwater Code in Arizona was also used in the arguments against the Central Arizona Project. As a result, Section 304(a) of the Act contains a prohibition against water from the Central Arizona Project being used to irrigate lands not having a recent history of irrigation (except lands located on Indian Reservations). "Recent history of irrigation" has been determined by the Secretary of the Interior to mean irrigation at some time between September 30, 1958, and September 30, 1968, the date on which the Act became law.

The Colorado River Basin Project Act was also instrumental in addressing on an annual basis the operation of the reservoirs of the Colorado River system to ensure that the needs of the users can be met and to conduct long-range assessments for the availability of water supplies. The Act directed the Secretary of the Interior to propose criteria for the "coordinated long-range operation of the reservoirs" in the Upper Basin with the operation of the reservoirs in the Lower Basin. Furthermore, the Act established the development of an Annual Operating Plan, in consultation with representatives of the seven Basin States to determine: (1) the projected operation of the Colorado River reservoirs to satisfy projected purposes under varying hydrologic and climatic conditions; (2) the quantity of water considered necessary as September 30 of each year, to be in storage in the Upper Basin reservoirs as required by the Act; (3) water available for delivery pursuant to the Mexican Treaty and Minute 242; (4) whether the reasonable consumptive use requirements of mainstream users in the Lower Basin will be met under "normal," "surplus," or "shortage" condition: and (5) whether water apportioned to, but unused by one or more Lower Basin States exists and can be used to satisfy beneficial consumptive use requests of mainstream user in other Lower Basin States as provided in the Decree.

B. Availability of the Colorado River Water

When the entitlements were identified in the Colorado River Compact in 1922, the river data showed an average annual flow of approximately 16 million acre-feet. At that time concerns were focused more on development of the river's supply in California and protecting development potential in the other States along the river, especially from the perspective of Colorado where the river originates. Since that time the mean annual flow of the Colorado River is estimated to be 14 million acre-feet. Currently, the Lower Basin is fully utilizing its 7.5 million acre-foot entitlement. Upper Basin demand is approximately 5 million acre-feet and Mexico is utilizing its full 1.5 million acre-foot entitlement.

"Shortages" on the River are determined separately in the Upper Basin from the Lower Basin. For the Lower Basin, conditions are assessed through the development of the Annual Operating Plan and a determination is made as to whether the system will be operated under "normal", "surplus" or "shortage" conditions based on the volume of water in Lake Mead, the projected inflow to the reservoir, and the current demand for water in the Lower Basin. ***Normal*** conditions exist when the annual pumping and/or release from Lake Mead is sufficient to satisfy 7.5 million acre-feet of annual consumptive use. Surplus conditions exist when the Secretary determines that mainstream water is available in excess of normal conditions. A ***surplus*** condition allows water to be divided among the three Lower Basin States with 50 percent to California, 46 percent to Arizona, and 4 percent to Nevada. Additionally, if all water demands for contractors in the U.S. are met during surplus or flood conditions, the Secretary may allow the additional delivery of 200,000 acre-feet to Mexico. A ***shortage*** condition exists when the Secretary determines that there is insufficient mainstream water available to satisfy annual consumptive use of 7.5 million acre-feet. An elevation trigger has been developed to identify a shortage condition at 1000 feet above mean sea level, which is the elevation of the intake for the Southern Nevada Water Authority, which develops and delivers Nevada's entitlement of 300,000 acre-feet. If projected inflows are insufficient to bring Lake Mead's elevation above 1000 feet and current demands meet or exceed 7.5 million acre-feet, the Secretary will declare a shortage on the River for the Lower Basin. Section 301(b) of the Basin Project Act states, "…that in any year in which, as determined by the Secretary, there is insufficient mainstream Colorado River water available for release to satisfy annual consumptive use of seven million five hundred thousand acre-feet in Arizona, California, and Nevada, diversions from the mainstream for the Central Arizona Project shall be so limited as to assure the availability of water in quantities sufficient to provide for the aggregate annual consumptive use by holders of present perfected rights, by other users in the State of California served under existing contracts with the United States by diversion works heretofore constructed, and by other existing Federal reservations in that State, of four million four hundred thousand acre-feet of mainstream water, and by users of the same character in Arizona and Nevada." Appendix V summarizes the priorities that apply within Arizona in the administration of Colorado River Mainstream Water and provides a listing of Colorado River contractors by priority order.

C. The Central Arizona Project

Because of the foresight of individuals early in the development of Arizona's water supplies, the Central Arizona Project provides additional resources to the central, most populous portion of the State. As described above, the development of the Central Arizona Project took many decades, but with the enactment of the Colorado River Basin Project Act, the Central Arizona Project became a reality. Construction began in 1974 with water deliveries to the Phoenix area beginning in 1985. The canal was extended to the Tucson area and was determined to be complete in 1995. The total cost of the project was $3.6 billion. The Central Arizona Project canal runs 336 miles from Lake Havasu to the San Xavier Reservation, 14 miles south of the City of Tucson. The Central Arizona Project canal will deliver an average of 1.5 million acre feet of Colorado River water annually, but can, if necessary, deliver up to approximately 2 million acre feet.

Figure 4: Central Arizona Project
Source: Central Arizona Project

Colorado River water is delivered to agricultural, industrial, Indian and municipal users in Maricopa, Pima, and Pinal Counties (see Figure 4). The Central Arizona Water Conservation District was created by Arizona Statute to manage the project and, through a contract with the Secretary of Interior, deliver water to contractors and sub-contractors. The amount of water available to the Central Arizona Project was identified in the Contract as any portion of Arizona's entitlement remaining after the needs of senior rightholders are met, less 164,652 acre-feet for users along the Colorado River holding the same priority (see Priority 4, in Table 2 above). In 1981, the Secretary of the Interior issued a Record of Decision allocating water developed by the Central Arizona Project to Indian and non-Indian water users. Since that time, the allocations have been modified to address adjustments resulting from Indian water rights settlements and other agreements, Allocations have been identified primarily for two sectors - (1) Municipal and Industrial (M&I) and (2) Indian – with any remaining or unused portion available for non-Indian Agriculture. Current municipal and industrial subcontracts total 556,680 acre-feet, divided among: cities, towns and water service organizations with definable growth patterns; copper mines; electric power industries; the Arizona State Land Department for new development on State Lands; and Maricopa County for park development. Indian Communities who hold contracts through the U.S. for irrigation, domestic or other uses on within their communities currently total 388,906 acre-feet.

In 1983, Secretary of the Interior Watt issued a revision of the Record of Decision that included a shortage sharing strategy. Although there are differences in interpretation of this document, the State of Arizona has interpreted the strategy to mean: first, delivery for miscellaneous uses would be reduced pro rata until exhausted; next, non-Indian agricultural uses would be reduced pro rata until exhausted; next, the Gila River Indian Community allocation would be reduced 25 percent and other Indian irrigation uses would be reduced 10 percent on a pro rata basis until exhausted; next, the non-Indian M&I uses would be reduced to 510,000 acre-feet. Thereafter, the remaining water contracted for by 11 Indian Tribal entities under existing contracts and 75 percent of the Gila River Indian Community allocation would share a priority with 510,000 acre-feet of M&I non-Indian uses[14].

Following the revision to the Record of Decision, the Secretary of the Interior and the Central Arizona Water Conservation District entered into contracts for delivery of water to several municipal and industrial water users that included inconsistent shortage sharing

[14] Arizona Department of Water Resources CAP Shortage Sharing History, T. Carr, July 28, 1998

provisions. Additionally, as claims by several Indian Communities were settled, the allocations for M&I and Indian users were adjusted based on these negotiated settlements, some to the detriment of users who were not party to the settlements, further confusing the shortage sharing strategy.

Both the State of Arizona and the Department of the Interior agreed that the current conflicting language could lead to litigation in the event of a shortage. The recent negotiations between the parties involved in the Gila River Indian Community Water Rights Settlement Agreement provided an opportunity to address several issues, including finding a solution to the shortage sharing issue. As a result, a single shortage sharing strategy has been developed through the Settlement Agreement that will be incorporated into all future modified contracts or subcontracts.

The Shortage Sharing Strategy that was negotiated through the Gila River Indian Community Water Rights Settlement Agreement requires non-Indian agricultural subcontracts to be relinquished and the relinquished subcontract allocations to be combined with uncontracted water. The subcontracts for non-Indian agricultural water are currently based on a percentage basis of water available in each year. The shortage sharing strategy modifies the quantification of non-Indian Agricultural allocations from a percentage, to an acre-foot per year amount. In the event of a shortage, non-Indian Agricultural uses will still be the first to be reduced. Although most planning studies envision shortage declarations that will result in no water being available for the non-Indian agricultural priority contracts, there is also the possibility that a portion of this water would not be made available as result of higher uses by municipal and industrial sub-contractors and Indian contractors (due to the fact the non-Indian agricultural portion includes the unused sub-contract and contract allocations). In anticipation of these possibilities, the proposed shortage sharing criteria call for an allocation of available water on a pro-rata basis. The measure of the pro rata calculation will be based on the amount of recent use. The exception to this method is that portion of the Gila River Indian Community's water use that it has under contract, but did not put to use because distribution systems have not yet been completed.

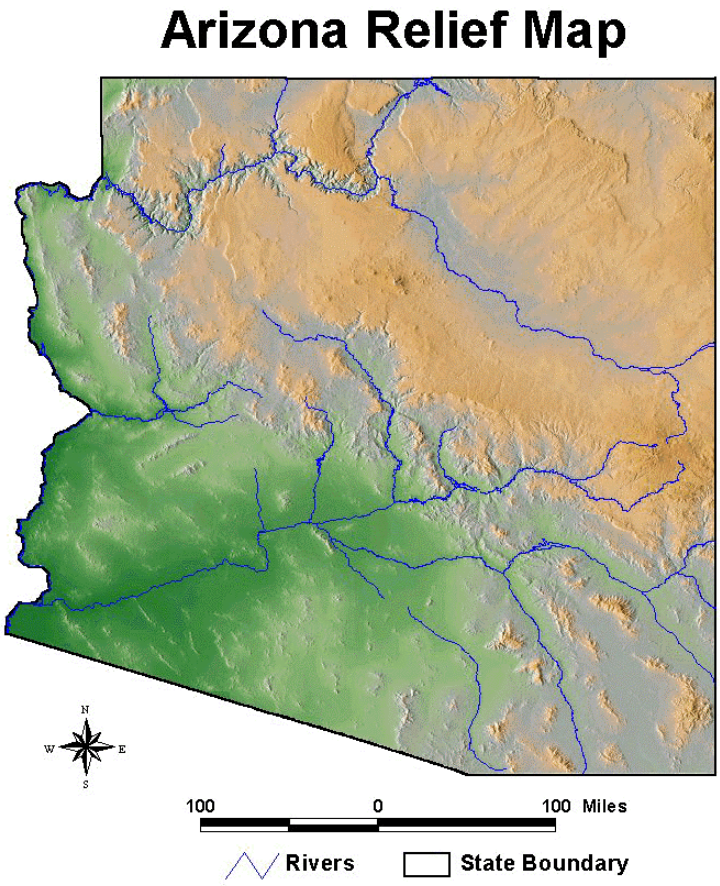
For M&I and Indian uses, the revised shortage sharing criteria eliminates many of the conflicting language and ambiguities that existed in the prior contracts. The new shortage sharing strategy is based on a fixed volume for the Indian priority pool and the M&I priority pool[15]. Furthermore, the strategy eliminates the steps that were used in the previous criteria and replaces it with a true co-equal priority. For any volume of water supply that may be available, an established formula calculates the total amount of water in the Indian pool and the M&I pool. The distribution of the available supply within each of the pools is then determined based on the percent of water recently used prior to the shortage. The sharing of shortages among Indian contractors is more complicated due to pre-existing conditions in several of the Indian contracts.

Even with a shortage sharing strategy in place, the fact that water from the Central Arizona Project has the lowest priority on the Colorado River system means that users are highly vulnerable to shortages. To address this issue a mechanism exists within Arizona's

[15] The M&I pool enlarges after the year 2044 in recognition of the conversion from non-Indian agricultural priority to M&I priority allowed in the Cliff Dam replacement contract.

water management structure to decrease the potential impact from future shortages. In 1996, Governor Symington and the State Legislature created the Arizona Water Banking Authority. Until the Arizona Water Banking Authority was created, Arizona did not use its full 2.8 million acre-foot share of Colorado River water. Without the Arizona Water Banking Authority, it was anticipated that Arizona would not have used its full allocation until the year 2030. During that interim period, the accumulated amount of water left in the Colorado River would have amounted to approximately 14 million acre-feet, most of it going to southern California. Water managers recognized that leaving a portion of Arizona's water in the Colorado River was a lost opportunity and that by storing Arizona's unused apportionment, a supply could be available to offset future shortages on the Central Arizona Project system. To date, the Arizona Water Banking Authority has stored approximately 2 million acre-feet of Colorado River water in Maricopa, Pima, and Pinal counties. Additionally, the Arizona Water Banking Authority stores water to protect Arizona's other Priority Four water users, located on the mainstream of the River (e.g., Mohave County Water Users). In times of shortage, stored water will be recovered to offset Central Arizona Project delivery shortages experienced by municipal and industrial subcontractors.

D. Surface Water Other Than Colorado River Water



Surface water from lakes, rivers and streams is another supply used in Arizona. Surface water is defined as "Waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwaters, wastewaters, or surplus water, and of lakes, ponds and springs on the surface."[Arizona Revised Statutes § 45-101] These surface waters are subject to the "doctrine of prior appropriation," which means that the first person to put water to beneficial and reasonable use acquires a superior right to later appropriators. This person, or their successors, has the right to use a specified amount of water for a stated beneficial use each year, subject only to the rights of prior appropriators. To make best use of surface

water when and where it is needed, storage reservoirs and conveyance systems have been constructed throughout the state. Major reservoir storage systems are located on the Salt, Verde, Gila and Agua Fria Rivers. Flow in the Santa Cruz River in the Santa Cruz, Tucson and Pinal Active Management Areas is extremely variable with effluent-dominated perennial reaches downstream from wastewater treatment plants in the Santa Cruz and Tucson Active Management Areas. In the southeastern part of the state, the San Pedro River supplies water for agricultural use. There are a number of other smaller streams and surface water impoundments throughout the state that provide a local water supply.

1) Surface Water Law

Some of the present day provisions of Arizona surface water law can be traced back prior to the Treaty of Guadalupe Hildago in 1848 by which much of Arizona and New Mexico was ceded to the U.S. by Mexico. [Water – A review of Rights in Arizona, Fred Struckmeyer, Jr. and Jeremy Butler, April 1960] As Arizona was originally part of the New Mexico Territory, the Territorial legislators addressed water rights in 1851 by providing "owners of tillable lands" the right to construct public or private ditches to access water supplies and further allowed these facilities to run through other properties, so long as those whose lands were being crossed were compensated. This implies a non-riparian approach to appropriating water supplies as landowners who are not necessarily adjacent to the channel were allowed to initiate a beneficial use of these supplies.

Arizona became a separate territory in 1864 and the first Arizona Territorial Legislature took action on surface water by declaring: "All streams, lakes, and ponds of water capable of being used for the purposes of navigation or irrigation, are hereby declared to be public property; and no individual or corporation shall have the right to appropriate them exclusively to their own private use, except under such equitable regulations and restrictions as the legislature shall provide for that purpose[16]." Later that same year the Territorial Legislature adopted a water code for the Territory, named the Howell Code after William T. Howell of Tucson who was appointed Code Commissioner. The Howell Code declared all rivers, creeks, and streams as public supplies and granted all inhabitants of the Territory the right to construct canals to access "the necessary water" to irrigate their lands "…from any convenient river, creek, or stream of running water." Additionally, the Howell Code addressed shortages in stating "…that during scarcity, the owners of fields shall have preference according to the dates of their respective titles, or occupation of the land, the oldest having preference." Even though the Territorial Legislature provided the ability to appropriate water for beneficial use, they did not address the mechanism to do so. This was not immediately an issue until increasing development coupled with drought towards the end of the 19th Century resulted in conflicts among users, especially on the Salt and Gila Rivers where development of agricultural lands was increasing significantly.

In 1893, the Territorial Legislature required new water appropriations to be posted at the point of diversion and recorded with the County Recorder. The priority date of the water right was date of the "recording" of the notice, if the water was subsequently put to a beneficial use, "within a reasonable time thereafter." This recording system remained in place until 1919, when the newly formed State of Arizona enacted the 1919 Public Water Code, which has essentially changed very little over time and makes up the

[16] Arizona Bill of Rights, Article 22

majority of the present Water Code (found in ARS 45-141, et. seq.). 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.

Although the 1919 Public Water Code addressed the means to perfect a surface water right for appropriators after the Code's enactment, appropriators prior to 1919 still were not statutorily recognized. A registry of all pre-1919 water rights claims was established in 1974 as a result of the Water Rights Registration Act, which allowed individuals alleging a pre-1919 surface water right to file a claim. This has resulted in over three decades of judicial proceedings to determine the extent and priority of water rights in the Gila River system and in the Little Colorado River system and the impact on post 1919 permits – through the Gila River Adjudication and the Little Colorado River Adjudication.

After the enactment of the Water Rights Registration Act, several entities filed petitions with the Arizona State Land Department (the Agency responsible at the time for water rights) to determine the water rights in the Salt River, the Verde River and its tributaries, the Gila River (both the Upper and portions of the Lower Gila River – including the Agua Fria River), Little Colorado River, the San Pedro River and its tributaries. At the time, there was litigation pending in federal court, which sought an adjudication of the Santa Cruz River watershed in Pima and Santa Cruz counties.

In November 1981, the Arizona Supreme Court adjudications were consolidated. Pursuant to statute, summons were issued in both adjudications and served on potential claimants (all persons listed in the property tax assessments in each watershed and on all persons in the watershed who had, at the time, any kind of water rights filing on record with the Arizona Department of Water Resources, which was created in 1980 and now headed State water rights filings and permits). The summons required the filing of a statement of claimant with if the person claimed a water use in the watershed. Nearly 25,000 parties in the Gila River Adjudication have filed more than 86,600 statements of claimant, and over 3,500 parties have filed over 12,600 claims in the Little Colorado River Adjudication[17].

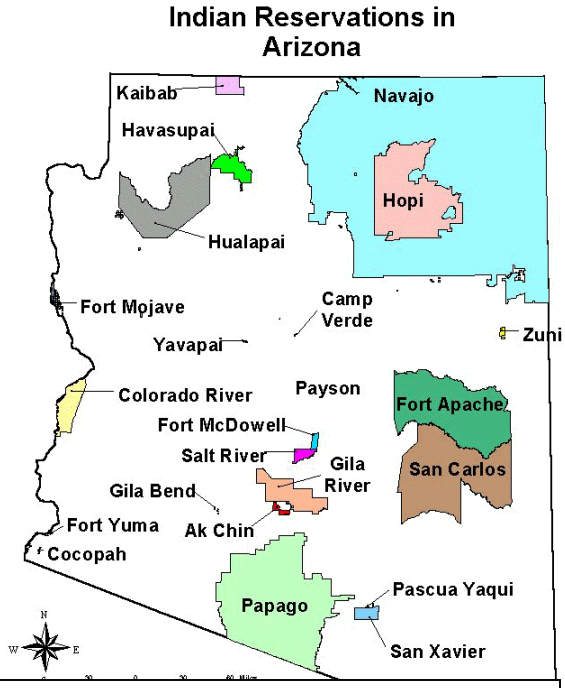


Figure 5: Location of Tribal lands in Arizona
Source: Dept of Water Resources

Among these statements of

[17] These totals include potential claimants who were served new use summons, those who have been initiated a new claim between July 1, 1991 and December 31, 2000, and who filed a claim as a result.

claimant are several Indian Communities and Federal entities. This is significant in that in 1908 the U.S. Supreme Court determined in *United States v. Winters*, that federal reservations were allocated enough water at the time the reservation was established to meet the purposes of the reservation - predating the surface water rights held by many non-Indian users. Many parties have engaged in negotiations to resolve Indian and Federal Reserved water rights by settlement. These efforts have resulted in the Maricopa County Superior Court's approval, following Congressional approval, of six settlement agreements of Indian reserved rights – the Ak-Chin Indian Community, the Fort McDowell Indian Community, the Salt River Pima Maricopa Indian Community, the San Carlos Apache Tribe (only the claims to the Salt River), the Yavapai-Prescott Indian Tribe, and the Tohono O'odham (although this has not yet been implemented). Negotiations to resolve the water right claims of several other Indian tribes have actively continued for several years. In 2003, the U.S. Congress approved the Zuni Indian Water Rights Settlement Agreement in the Little Colorado River Adjudication. Currently, Congress is considering another Indian water rights settlement act, the largest is U.S. History – the Gila River Indian Community. Although these settlements do not completely resolve the pending adjudications, the final Decrees will establish the existence and ownership of claimed water rights as well as important attributes of the water rights including location of diversions, water uses, quantity of water used, and date of priority of water rights.

E. Groundwater

Groundwater has long been an important reliable source for many parts of this State. However, groundwater pumping over many decades has resulted in overdraft in some parts of the State. Overdraft occurs when more groundwater is withdrawn than is replaced by natural or artificial recharge. Decreasing reliance on groundwater supplies in Arizona, while maintaining the state's economy, has proven to be a complicated and challenging task. The recognition of the need to manage the State's groundwater resources has been a long process culminating with the development and adoption of the 1980 Groundwater Management Act.

1) History of Groundwater Law in Arizona

The history of groundwater management in Arizona did not begin with the passage of the 1980 Groundwater Management Act. The increasing need for groundwater has created a long history of litigation. Although surface water law was developed through constitutional and statutory provisions, groundwater law has been interpreted from common laws through the courts [18].

Subsurface waters were separately identified, by the Courts, as either flowing in underground streams or as percolating through the soil beneath the land surface. Beginning as far back as 1904, the Arizona Territorial Supreme Court adopted the common law rule that percolating water was the property of the overlying landowner and not subject to appropriation as surface water[19]. This decision was reinforced in 1918

[18] Desmond D. Connal, Jr., 1982, A History of the Arizona Groundwater Management Act, Arizona Law Journal, pp 313 – 344.
[19] Howard v. Perrin, 8, Ariz. 347, 76 P. 460 (1904), *aff'd*, 200 U.S. 71 (1906)

when the courts classified subsurface spring water as non-appropriable groundwater[20]. In 1926, subsurface water flowing in natural channels between well-defined banks, was affirmed by the courts to be subject to appropriation[21]. In 1931, the courts declared percolating water not to be part of an underground stream or sub-flow, again affirming groundwater as a non-appropriable water supply. Additionally, the burden of proving an underground stream was placed on the person who is claiming the existence of such water for appropriation[22].

In the 1930's, the combination of increased cotton prices, improved technology in well pumping efficiency, and the availability of inexpensive power led to increased groundwater pumping. As a result, individual well owners experienced declining water levels and difficulty producing water. Well owners began to compete for the supply as adjacent wells impacted each other, leading to litigation. In response to growing concerns over increased groundwater pumping, in 1938 the first commission to study groundwater was appointed by Governor Stanfield. The only thing the commission was successful in accomplishing was convincing the legislature of the need to appropriate funds to have the U.S. Geological Survey (USGS) investigate and prepare a report on groundwater conditions in the state. The report, issued by the USGS in 1943, found that groundwater depletion would continue to increase further, as more lands were developed for farming. In order to limit the expansion of agricultural development, existing irrigation districts favored making Arizona's groundwater a publicly owned, instead of a privately owned resource. This would ensure that existing farmers would have the priority to continue farming and utilize the water supply, without competition from new farming operations. As a result of the USGS report, two bills were introduced in the 1945 legislative session. These bills would have 1) quantified and appropriated groundwater among the existing users; 2) limited or eliminated additional farming operations and 3) required the registration of all irrigation wells, however, neither bill was passed.

At the same time the state was struggling with the groundwater situation, some of the state's top officials were also working on augmenting the State's existing supplies through conveyance of Colorado River water to central and southern Arizona as discussed in the previous section. In what would only be the beginning of the federal government's role in moving the state towards legislative groundwater management, the Bureau of Reclamation declared that the Central Arizona Project would not be approved until Arizona took steps to restrict agriculture irrigated with groundwater. In response, Governor Osborn reintroduced both bills in a special session. The well registration bill, which only required the registration of all wells throughout the state, was better received and became the Groundwater Code of 1945. It was immediately recognized that the 1945 Code did nothing to stop agricultural development and again in 1948 the federal government threatened to eliminate funding for the Central Arizona Project.

A Groundwater Code was finally enacted in 1948, after six special sessions, that provided for designation of ten critical areas within the state (defined as areas without sufficient groundwater to provide irrigation for cultivated lands at current rates of withdrawal), prohibited the expansion of agriculture irrigated with groundwater within the

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[20] McKenzie v. Moore, 20 Ariz. 1, 5, 176 P.568, 569 (1918)
[21] Pima Farms Co. v. Proctor, 30 Ariz. 96, 245 Pac. 369 (1926)
[22] Maricopa County Municipal Water Conservation Dist. No. 1 v. Southwest Cotton Co., 39 Ariz. 65, 73, 4 P. 2d 369 (1931), reh. 39 Ariz. 367, 7 P. 2d 254 (1932)

critical groundwater areas, and allowed existing pumping to continue. Allowing continued pumping at historic levels in the critical groundwater areas and not apportioning groundwater use among the overlying landowners within the critical areas were problems. In response, a second groundwater study commission was, in 1951, charged with drafting a meaningful groundwater bill. The commission introduced a bill in the 1952 legislative session that would not only divide the state's groundwater basins into three separate management classifications but also, and most notably, changed the long-held common law rule of groundwater use to a publicly-owned resource subject to appropriation, however, this failed to pass. Additionally, during the 1950's, a series of Arizona Supreme Court decisions and additional groundwater study commissions failed to develop meaningful groundwater legislation.

Meanwhile, the State's dependence on groundwater was continuing to increase. Coupled with extended droughts on the Salt and Verde River watersheds between 1942 and 1948 and again between 1953 and 1957, groundwater was legally being pumped at rates that far exceeded recharge[23]. The concept that the water beneath the land belonged to the landowner, together with the doctrine of reasonable use, encouraged landowners to pump as much water as they could use without regard to the impact on neighboring wells. The fact that all pumping from the common source affects all the overlying was still largely ignored.

Although the 1948 Code put restrictions on development of new agricultural lands (although it lacked any enforcement provisions), it was silent on obtaining water to supply new non-agricultural development. Cities and towns relied on transporting groundwater from one location (where the well is located) to another location where the water is put to use. Although the area of pumping and the area of use were usually within the water service area of the water provider, in some instances water was being pumped from outside the service area and transported back to the service area for domestic and industrial uses. This situation would lead the state towards yet more complicated litigation. In fact, one of the issues that ultimately led to the development of groundwater management in Arizona was the transportation of groundwater.

In a series of decisions between 1969 and 1974, the Arizona Supreme Court tried to tackle the issue of transportation of groundwater. In response to a lawsuit filed in 1969, the court issued an injunction against the City of Tucson prohibiting the transportation of groundwater from its well fields in the Avra and Altar Valleys, which had been designated as a critical area[24]. The Court held that the property right in percolating waters was only a right to use the water, limited by reasonable use, on overlying land, not ownership of the source. Subsequently, in 1970, the Court modified its injunction on Tucson based on surface water statute (ARS 45-147) for determining appropriative rights which gives preference to municipal and domestic uses over agricultural uses. The Court interpreted the statute to mean that municipal uses were higher in priority to agricultural uses and allowed Tucson to purchase and retire irrigated farmlands and transport the "annual historical maximum use" of groundwater applied to the irrigated acreage[25]. This allowed the City of Tucson to annually pump the highest amount of groundwater used on

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[23] Beddome, Larry. Undated Publication. History of Surface Water Law in Arizona and within the Salt River Valley: To Protect Our Water Supply. 12 p

[24] Jarvis v. State Land Department (Jarvis I), 104 Ariz. 527, 456 P. 2d. 385 (1969)

[25] Jarvis v. State Land Department (Jarvis II), 106 Ariz. 506, 479 P. 2d. 169 (1970)

the farm in a single year, thus allowing more pumping than ever. In 1974, the Court finally modified its previous decision and limited the pumping by the City of Tucson to 50 percent of the "annual historic maximum use[26]."

During this time, what is often considered the single event that prompted the passage of the 1980 Groundwater Management Act, was being argued in the Arizona Supreme Court, Farmers Investment Company v. Bettwy, 113 Ariz. 520, 558 P 2d. 14 (1976). Anamax, a mining company south of Tucson, was constructing a well in the Sahuarita-Continental Critical Groundwater Area to provide water for its mining operations several miles away to mines located outside the critical groundwater area. Farmers Investment Company, who owned approximately 7,000 acres of farmland within the critical groundwater area, sued to stop Anamax from completing its well, claiming that the use of the water was outside "the land from which the water was taken" and violated the reasonable use doctrine established in (*Bristor v. Cheatham*, (Bristor II), rev. 75 Ariz. 227, 255 P2d. 173 (1953))[27].

In its decision, the Court recognized that the State had been committed to the reasonable use doctrine in an earlier case (*Bristor II)* and had operated for almost 50 years in this manner. In favor of Farmers Investment Company, the Court confirmed that under the doctrine of reasonable use water could not be pumped from one area and transported to another area, even if both areas overly a common source, if other wells suffered injury or damage. The Court went further, based on the same opinion, and limited the City of Tucson to withdrawals in the amount pumped before 1972, the date of its intervention in the case. In summary, the Court gave Farmers Investment Company the right to seek an injunction against the mines and the City of Tucson from transporting groundwater[28].

The impact of this decision was a great blow to the second and third largest water users in the state. Farmers Investment Company was persuaded to forgo its injunction, rather choosing to seek a settlement. However, this did not end the legal interpretation of the phrase "the land from which the water is taken" and the issue of transportation of groundwater from the critical groundwater areas remained uncertain.

In 1976, the mines and the cities formed a tenuous alliance. The mines' were primarily interested in changing the transportation rules. The cities shared, to some degree, this interest, however, their primary objective was to conserve groundwater for supplying the expanding urban areas[29]. The newly formed alliance approached the agricultural interests within the state to discuss possibilities for new groundwater legislation. The farming community was opposed to the transportation of groundwater, believing that it would increase the depletion of the farmer's water supply, and refused to participate. However, in 1977 the three parties were persuaded to come together by Senator Alfredo Guitierrez and Representative Burton Barr to draft amendments to the 1948 Code. Concurrently with the discussions on groundwater management, the Federal government again weighed in on the Central Arizona Project. President Carter announced that among

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[26] Jarvis v. State Land Department (Jarvis III), 113 Ariz. 520, 588 P. 2d. 14 (1976)
[27] Clark, Emmett C., Arizona Water Resources Management Act of 1977 (A Proposed Water Resources Code or Statute), University of Arizona College of Law, 1977, 116 pp
[28] Desmond D. Connal, Jr., 1982, A History of the Arizona Groundwater Management Act, Arizona Law Journal, pp 313 – 344
[29] Philip Higdon and Terrence W. Thompson, 1980, The 1980 Groundwater Management Code, Arizona Law Journal, pp 621 – 667

other water projects in the United States the Central Arizona Project would be cut from the federal budget. Although later removed from the "hit list", Secretary of the Interior, Cecil Andrus, warned that if Arizona failed to enact a groundwater code, the Central Arizona Project would be eliminated.

In the spring of 1977, the amendments to the 1948 Code were passed. The provisions of the 1977 Act were "intended to apply only until a comprehensive plan providing for groundwater use, allocation, and distribution…" were implemented[30]. The 1977 Act established a permit system allowing for the transportation of groundwater (again, pending the adoption of a groundwater code) and created a twenty-five-member Groundwater Study Commission (Commission) that was charged with developing a comprehensive groundwater code for Arizona. The Commission was required to prepare a draft report by June 30, 1979 and a final bill by December 31, 1979. To address the lack of effective groundwater management throughout Arizona's history, a provision was included that the Commission's proposal would become law if the Legislature failed to enact groundwater legislation by September 7, 1981.

It is important to note that only the agricultural, mining, and municipal interests were involved in the Groundwater Study Commission discussions. Private water companies and developers, who would become important as the 1980 Code was implemented, were not present. The Commission was given two years to develop a groundwater code and submit legislation that would be acceptable to the major water users in the State, ensuring its immediate passage. Coupled with the increasing pressure from the Federal government to make genuine on its threats to cancel financing of the Central Arizona Project, the Commission was faced with balancing conflicting interests in a way that would ultimately become law, and doing so under the continuing pressure of a deadline.

2) The 1980 Groundwater Management Act

In 1979 the Groundwater Study Commission released its draft report and in1980 the legislature passed the Groundwater Management Act. The Groundwater Management Act established the Arizona Department of Water Resources, with a Director appointed by the Governor, to administer its provisions. . The Arizona Department of Water Resources was charged with management of all groundwater resources in Arizona facilitate by the creation of four initial active management areas: Phoenix, Pinal, Prescott, and Tucson, and the formation of two irrigation non-expansion areas: St Johns and Douglas. The Groundwater Management Act also contains a number of important groundwater management components that are briefly summarized in the following sections.

a. Management Goals and Management Plans

Each of the initial Active Management Areas was assigned a "safe-yield" management goal except for the Pinal Active Management Area, which was assigned a goal that allows for economically feasible agricultural use of groundwater while preserving future water supplies for non-irrigation uses. The Code defines safe-yield as "…a groundwater management goal, which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management

[30] Clark, Emmett C., Arizona Water Resources Management Act of 1977 (A Proposed Water Resources Code or Statute), University of Arizona College of Law, 1977, 116 pp

area[31]." In order to achieve the management goals, five management periods were established, between 1980 and 2025. For each management period, the Director of the Arizona Department of Water Resources must establish conservation requirements for all persons withdrawing, distributing or receiving groundwater designed to achieve reductions in withdrawals of groundwater.

Industrial users (including mines, golf courses, schools, parks, dairies and feedlots) are required to use the latest available conservation method consistent with reasonable economic return. All industrial users are subject to general conservation requirements that include avoiding single-pass cooling unless the water is reused, reuse or recycle water if possible, use low-flow plumbing fixtures as required by state law and use low water use landscaping. In addition, specific water conservation requirements apply to certain types of industrial users.

Cities, towns, private water companies, and irrigation districts that deliver water for non-irrigation (non-agricultural) purposes are subject to gallon per capita water per day conservation requirements. However alternative conservation programs that require specified conservation practices have also been developed to meet this requirement.

Agricultural water use is subject to a "water duty", also established by the Director. Similar to the municipal users, alternative conservation programs are available to agricultural users that provide management flexibility. With each successive management period, the conservation requirements become progressively more stringent, within reason.

b) Groundwater Rights

The Groundwater Management Act also established a system of groundwater rights. Grandfathered Rights were established for existing groundwater users. An Irrigation Grandfathered Right allows for the irrigation of commercial farmland. Each Irrigation Grandfathered Right is assigned a maximum annual water duty allotment. The irrigation water duty is "…the quantity of water reasonably required to irrigate the crops historically grown in a farm unit including lined ditches, pump-back systems, land leveling, and efficient application practices…". The term "crops historically grown" was interpreted to mean the crops grown on actively irrigated farmland in the five years preceding the Code (1975 – 1979). Irrigation Grandfathered Rights are appurtenant to the land and cannot be severed or sold separately.

Additional Grandfathered Rights established under the Code are Type I Non-Irrigation Grandfathered Rights and Type II Non-Irrigation Grandfathered Rights. A Type I Non-Irrigation Grandfathered Right is established through the retirement of legally irrigated farmland and allows for withdrawals up to three acre-feet per acre. These rights are appurtenant to the retired irrigated land on which they are based and must be sold with the land. Type II Non-Irrigation Grandfathered Rights are not appurtenant to the land and can be sold independent of the land. Type II Non-Irrigation Grandfathered Rights are based on historic non-irrigation withdrawals prior to 1979.

The Groundwater Management Act also identifies groundwater withdrawal permits for new non-irrigation uses: Dewatering Permits, Mineral Extraction and Metallurgical

[31] 1980 Groundwater Management Code, Title 45 Arizona Revised Statutes, Sections 401 through 636

Processing Permits, General Industrial Use Permits, Poor Quality Groundwater Permits, Emergency Dewatering or Electrical Energy Generation Permits, and Drainage Water Withdrawal Permits. Each permit is issued for specific uses and for a specified duration.

Water deliveries to domestic customers are permitted under a Service Area Right. A service area is the area that contains an operating distribution system for delivery of non-irrigation water. Under the management plans, large municipal providers (a city, town, private water company, or irrigation district delivering water in excess of 250 acre-feet per year for non-irrigation uses) are subject to conservation requirements based on per capita water use reductions. Holders of service area rights have the right to withdraw as much groundwater from within their service area as needed to serve their customers, subject to conservation requirements in the management plans and the Assured Water Supply Rules, as applicable. Service Area Rights can only be expanded for cities, towns, and private water companies under certain conditions.

c) Assured & Adequate Water Supply Provisions

The Groundwater Management Act requires that all land that is subdivided for sale or lease comply with the assured or adequate water supply provisions depending on whether the subdivision is within or outside of an AMA. The Department of Water Resources in February 1995 adopted the Assured and Adequate Water Supply Rules. Outside of the Active Management Area, developers can apply for a Statement of Water Adequacy or are required to disclose any "inadequacy" of the supply to the initial lot buyer. Water providers outside of Active Management Areas may also choose to obtain a Designation of Water Adequacy in which case developers are not required to submit plans for their subdivision's water supply if the lots will be served by the designated water provider. More rigorous provisions for new subdivisions are contained in the Assured Water Supply Rules inside the Active Management Areas. The sale or lease of subdivided land in an Active Management Area is prohibited 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. In Active Management Areas, new subdivisions are required to have a Certificate of Assured Water Supply, unless a water provider with a Designation of Assured Water Supply can serve them. Both municipalities and private water companies must demonstrate the ability to provide sufficient water for existing and new development in order to be designated as having an assured water supply. Further, the use of such water must also be demonstrated to be consistent with the management plan and management goal of the AMA, and cannot be demonstrated on groundwater supplies.

d) Groundwater Transportation

Statutes governing the transportation of groundwater within and between basins are designed to protect hydrologically distinct sources of groundwater supplies and the economies in rural areas by ensuring the groundwater is not depleted in one groundwater basin to benefit another. In general, groundwater cannot be transported between groundwater basins or from a groundwater basin into an Active Management Area except for specific transfers specified in statute. A.R.S. § 45-551. Under current statute, groundwater can legally be redistributed within a subbasin, or within a basin that has not been divided into sub-basins, without payment of damages (A.R.S. § 45-541 and A.R.S. § 45-544). Groundwater may also be transported between sub-basins in the same basin, subject to payment of damages. A.R.S. §§ 45-542 *et seq.*

Therefore, within an Active Management Area, groundwater withdrawn and used within the service area of a city, town, private water company or irrigation district may be transported within a sub-basin subject to the requirements for location of use on that Grandfathered Right or withdrawal permit. Transportation of groundwater of up to three acre-feet per acre across sub-basins or away from the Active Management Area is allowed for Irrigation Grandfathered Rights and Type I Non-Irrigation Grandfathered Rights (with some limitations), for use on acres appurtenant to that right. Transportation of groundwater across sub-basins or away from an Active Management Area for use within the same municipal service areas or irrigation district, or pursuant to a Type 2 Non-Irrigation Grandfathered Right, a groundwater withdrawal permit or from an exempt well is allowed subject to payment of damages.

As with many portions of the statutes, the section pertaining to groundwater transportation includes exceptions and allowances for unique circumstances. Some allowance for transportation of groundwater from outside of an Active Management Area is included for cities that purchased irrigated farmland prior to 1988.

e) Water Augmentation and Recharge

Water augmentation activities have resulted in the underground storage (recharge) of large volumes of Central Arizona Project water and effluent in the Phoenix, Tucson, Pinal and Prescott Active Management Areas. The goals of the recharge program are to encourage the use of renewable water supplies, allow for flexible storage of supplies not currently needed, and to preserve groundwater supplies. Recharging renewable water supplies that would otherwise be unused provides a supply during periods of extended drought and may help meet water management objectives such as replenishing areas that have been over-pumped. Another program goal 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 pipeline distribution systems.

F. Effluent

Effluent, or treated wastewater, can be treated to a quality that can be used for purposes such as agricultural irrigation, turf grass watering, industrial cooling, or maintenance of riparian areas. Effluent has the potential to replace a potable water supply when potable water quality is not necessary for the use. Effluent can also be recharged to groundwater aquifers for future withdrawal and use or can be left in place to help replenish an aquifer or stabilize groundwater declines. Effluent is becoming an increasingly important water supply in both urban and rural areas of the state and can be of significant importance as a drought mitigation strategy.

In the Active Management Areas the management plans contain a number of effluent use incentives. For example, effluent is not included in the calculation of the municipal gallon per capita per day conservation requirement and turf-related facilities can use more water for irrigation if effluent is part of the supply. If 100% effluent is used by a rightholder, then the regulatory provisions of the Groundwater Management Act do not

apply at all since regardless of its original source, effluent is legally a separate type of water.

Outside of Active Management Areas, particularly in communities with water supply concerns, effluent is being utilized to meet non-potable water demands. Other communities are recharging effluent for the express purpose of aquifer replenishment.

Chapter 4 – Workgroup Reports

To develop the Arizona Drought Preparedness Plan, the Governor's Drought Task Force requested the assistance of climate and water supply experts to develop triggers for identifying the inset of drought conditions, creating a Monitoring Committee. Additionally, Impact Assessment Workgroups were identified to assess the impacts of drought, identify regional vulnerabilities, identify potential mitigation and response options, and identify adaptation strategies to reduce drought impacts within the major water using sectors.

The Impact Assessment Workgroups created by the Governor's Drought Task Force include the following:

1. Commerce, Recreation and Tourism;
2. Environmental Health, Watershed Management, Livestock, and Wildlife;
3. Irrigated Agriculture;
4. Municipal and Industrial; and
5. Tribal

The Monitoring Committee and Impact Assessment Workgroups are an integral component in the development of the Arizona Drought Preparedness Plan, as these groups have included and will continue to include input from the public and will be the primary focus point for public involvement and input throughout the development of the Arizona Drought Preparedness Plan. Members of the Monitoring Committee and the Impact Assessment Workgroups include members of the Governor's Drought Task Force, individuals with a wide range of expertise and experience within the sector. The workgroups were co-chaired by Arizona Department of Water Resources staff and external representatives of the sectors.

A. Monitoring Committee

The Monitoring Committee provided guidance in the development of a comprehensive monitoring network and will be the core of the ongoing effort to monitor and assess drought conditions in the state forming the basis of the drought adaptation and response activities. The objective of this Committee was to develop a drought monitoring system that provides detailed assessment data for decision makers in key government and economic areas impacted by drought. A key outcome of this effort is that Arizona will have a web based Drought Monitor report that contains a climate assessment, weather outlook, stream flow/runoff forecast (Jan-May), reservoir storage assessment and identification of drought decision triggers. The approach that has been developed for the Arizona Drought Preparedness Plan is modeled after an approach developed by Georgia Tech University; using data compiled for specific indicators within each Climate Division compared against historic data and averaging the datasets to come up with a value that is then compared to trigger levels that have been developed for Arizona. Additionally, information derived from observations at the local level will be used to corroborate the compiled datasets. For example, the USDA Natural Resources Conservation Service field offices will be preparing quarterly reports on conditions in each portion of the state. The University of Arizona Cooperative Extension, the US Department of Agriculture Farm Services, and the Arizona Game and Fish Department will be asked to collaborate on similar reports on a regular schedule.

The drought indices, monitoring techniques and trigger points will be further refined in the future to respond to the varied landscape types in Arizona's primary physiographic regions (basin and range, Mogollon Rim, Colorado plateau) and the influence of local and regional elevation-induced weather and climate patterns. This process will be amended over time as improvements are made and additional information becomes available. The complete report developed by the Monitoring Technical Committee is contained in Appendix VI.

B. Commerce, Recreation and Tourism Workgroup

The Commerce, Recreation and Tourism Workgroup focused primarily upon the identification and evaluation of significant economic impacts associated with drought and the development of mitigation strategies to address these negative impacts. Key stakeholder groups include local, regional and state economic development professionals, land and resource professionals within Arizona State government, economists within academia, Federal land and resource program managers, and elected officials. The complete report developed by the Commerce, Recreation and Tourism Workgroup is contained in Appendix VII.

C. Environmental Health, Watershed Management, Livestock & Wildlife Workgroup

The Environmental Health, Watershed Management, Livestock & Wildlife Workgroup focused on ecosystem health and those who depend on healthy ecosystems to function. The workgroups objectives included: (1) Identify the information and resources necessary to develop a statewide, comprehensive monitoring and assessment program to identify the onset of drought and its impacts on wildlife, livestock, and ecosystems in the State of Arizona; (2) Identify existing and alternative emergency response options that can be used to mitigate the impacts of drought on wildlife, livestock, and ecosystems in the State of Arizona; and (3) Develop mitigation and adaptation strategies to minimize to the extent possible the impacts of drought on wildlife, livestock, and ecosystems in the State of Arizona. The complete report developed by the Environmental Health, Watershed Management, Livestock & Wildlife Workgroup is contained in Appendix VIII.

D. Irrigated Agricultural Workgroup

The Irrigated Agricultural Workgroup focused on Arizona's irrigated agriculture sector, including individual irrigators and irrigation districts, dairies, and feedlots. Key stakeholders include individual farm operators, irrigation districts, and affiliated organizations. The objective of the Irrigated Agriculture workgroup is to assess the vulnerabilities, risks, and impacts of drought on the sector and to develop response, mitigation, and adaptation strategies to sustain the long-term economic viability of the State's irrigated agriculture. The complete report developed by the Irrigated Agriculture Workgroup is contained in Appendix IX.

E. Municipal & Industrial Workgroup

The Municipal & Industrial Workgroup focused primarily on rural area municipal and private potable water providers. Key stakeholder groups include water providers, jurisdictions, rural watershed partnerships, and industry associations. The objective of this workgroup is to assess vulnerabilities, identify sector specific monitoring needs, and

develop mitigation strategies to address drought related impacts on potable water supply systems, exempt wells, and public health conditions. The Arizona Department of Water Resources 2003 Rural Water Resources Study Questionnaire, the Arizona Corporation Commission and the Arizona Department of Environmental Quality programs, stakeholder input, the Conservation Committee, and other sources provided critical information for this process.

The Municipal and Industrial Workgroup Report is contained in Appendix X. Among other things, the report outlines strategies to reduce vulnerability to drought. One effective strategy includes long-term water supply planning as well as developing emergency operation plan to address short-term shortages or system disruptions. Supply side strategies include construction of additional storage facilities, acquisition of additional water sources, maximizing existing supplies by making capacity improvements to existing wells, water treatment plants, or through groundwater recharge; and water reuse. Additionally, demand side strategies have been identified including making distribution system improvements, water conservation, landscape irrigation requirements and water restrictions, conservation inducing water rates or rate structures, and implementation of innovative water collection techniques such as gray water reuse or rainwater harvesting to help reduce water demands. Further, the report contains a summary of the Municipal and Industrial Workgroup Drought Survey and Responses; an identification of vulnerability issues identified through the 2003 Rural Water Resources Survey; and a listing of Municipal Drought Management Plans, Curtailment Plans, and Ordinances.

F. Tribal Workgroup

The Tribal Workgroup focused on identifying the impacts of drought on Tribal lands within Arizona, integrating monitoring efforts with the tribal communities, and identifying response and mitigation options that could be implemented on tribal lands. There are 22 federally recognized tribes within the State of Arizona with an estimated combined population of 255,879 (2000 Census) occupying approximately 28 percent of the total land area in the State. Although tribal residents experience the same impacts as non-Indian communities across the State, some can be more vulnerable to drought conditions due to the reliance on individual domestic wells, lack of sufficient infrastructure and storage, and in some cases the remoteness of smaller communities, which is why it is extremely important to recognize and identify the impacts of drought on this sector. To facilitate this effort, the Governor's Drought Task Force has been working with the Inter Tribal Council of Arizona and the Arizona Commission on Indian Affairs, as well as meeting individually with tribal representatives to solicit input into this process. Impacts, mitigation, and response options on Tribal lands are similar to those identified by each of the sector workgroups which are contained in the Workgroup Reports identified above. A White Paper developed Inter Tribal Council of Arizona for the Governor's Drought Task Force is included in Appendix XI.

G. Other Impact Assessments

Several themes related to impacts and vulnerabilities consistently emerged from the workgroup discussions. These themes focused on energy, health, and water quality. White Papers for these areas are contained in Appendix XII.

Appendix I
GOVERNOR'S EXECUTIVE ORDER 2003-12

ARIZONA DROUGHT TASK FORCE PLAN

WHEREAS, precipitation throughout the State of Arizona during the past four years and for six of the last seven years has been significantly below normal; and

WHEREAS, the lack of precipitation has significantly reduced stream flows in the State's interior basins and reduced surface and groundwater supplies upon which citizens and the commerce of the State are dependent; and

WHEREAS, the lack of precipitation has created drought conditions throughout the state and most critically in the rural areas of the State; and

WHEREAS, the drought endangers people, property, crops, livestock and wildlife throughout the State of Arizona; and

WHEREAS, droughts are a periodically reoccurring event in Arizona and the arid southwest; and

WHEREAS, the adverse impacts of the drought can be mitigated by proper coordination of activities;

NOW, THEREFORE, I, Janet Napolitano, Governor of the State of Arizona, by virtue of the authority vested in me by the Constitution and Laws of the State, do hereby order the creation of a Drought Task Force, and further order as follows:

1. Under the leadership of the Department of Water Resources, the Drought Task Force shall:

    A. Identify water companies/providers that will have difficulty meeting their potable water demands this year.

    B. Identify locations in the state where drought-related water level declines are causing, or are likely to cause, significant losses of supply for individual domestic wells.

    C. Identify areas in state where water availability has declined and there will be insufficient water to sustain agricultural operations including crops and 1ivestock.

    D. Identify locations in state where reduced water availability is impacting wildlife and wildlife habitat.

    E. Develop and implement short-term drought plans to respond to and mitigate water shortages identified in items A through E above.

F. Develop and implement long-term drought mitigation plans for the state including thresholds for declaring a state of emergency and/or asking for the declaration of a federal disaster.

G. Develop and implement a statewide water conservation education strategy that emphasizes educational advertising for good water habit development.

H. Evaluate opportunities for more efficient use of water to meet agricultural and municipal needs.

I. Evaluate the availability of water for wildfire suppression and develop a plan for alternative supplies.

J. Assume the lead role in intergovernmental drought response coordination and media information releases, which shall be coordinated through and released by the Governor's Office.

K. Provide guidance and information to the Governor should conditions constitute the declaration of an emergency.

2. The Drought Task Force shall consist of one member selected by the Governor from each of the following agencies or entities:

A. Office of the Governor
B. Arizona Corporation Commission
C. Arizona Department of Agriculture
D. Arizona Department of Commerce
E. Arizona Department of Environmental Quality
F. Arizona Department of Health Services
G. Arizona Department of Real Estate
H. Arizona Department of Water Resources
I. Arizona Division of Emergency Management
J. Arizona State Land Department
K. Arizona Department of Homeland Security
L. Arizona Department of Transportation
M. Arizona Game and Fish Department
N. Arizona House of Representatives
0. Arizona State Senate

In addition, representatives from Arizona Counties, Cities, Towns and Indian Tribes and representatives from all water and power utilities in the state will be invited to participate. Federal agencies with drought response and recovery programs may be asked to act as advisors to the Task Force. Al! meetings shall be open to the public and the public will be encouraged to attend.

3. The Task Force may create work groups to address specific problem areas and shall create the following specific work groups:

   A. **Municipal and Industrial Water Supply -** This group shall make assessments and develop mitigation strategies including opportunities to increase water use efficiency for drought related impacts on public water supply systems (including both public and private water companies), exempt wells, and public health conditions.

   B. **Agriculture -** This group shall make assessments and develop mitigation strategies including opportunities to increase water use efficiency for drought related impacts on agriculture including crops and livestock.

   C. **Wildlife and Wildlife Habitat -** This group shall make assessments and develop mitigation strategies for drought-related impacts on Arizona's wildlife and wildlife habitat.

   D. **Conservation Education -** This group shall design an educational advertising plan for use in water conservation education throughout the state, but focused on rural areas. It shall also assess available, no-cost public interest media opportunities to convey plan messages as well as identify potential contributors for additional paid media spots.

   E. Fire Suppression - T-his group will make assessments of existing water supplies available and develop a plan for alternative water supply options for suppression of wildfire.

IN WITNESS WHEREOF, I have hereunto set my hand and caused to be affixed the Great Seal of the State of Arizona.

GOVERNOR

Done at the Capitol in Phoenix this 20th day of March in the Year Two Thousand Three and of the Independence of the United States of America the Two Hundred and Twenty-Seventh

ATTEST:

SECRETARY OF STATE

Appendix II

POTABLE WATER PLAN 2003
&
POTABLE WATER PLAN 2004

Governor's Drought Task Force

Potable Water Plan

July 10, 2003

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Executive Summary

The Potable Water Plan is a result of the leadership provided by Governor Napolitano through Executive Order 2003-12. The Executive Order created the Governor's Drought Task Force to develop a long-term drought plan, a statewide water conservation strategy and to address short-term water needs.

The Potable Water Plan addresses short-term water supply for political subdivisions under emergency conditions where the health and welfare of the public is at risk. The Plan introduces a methodology based on planning guidance from the National Drought Mitigation Center. There are three basic elements to the Plan: Monitoring, Assessment and Response. Each section describes specific mechanisms to provide data, determine potable water drought related risk factors, and provide response guidance to political subdivisions of the State. The Monitoring function identifies a web site where the latest climate discussion is updated, as new information is available. The Assessment discussion identifies water providers that face potable water delivery challenges due to drought and provides a vulnerability profile. The profile enables rural water providers (where nearly all of the potable water shortage risk is associated) to determine their own risk to drought as conditions change. The Response discussion directs at risk water providers to the appropriate response mechanism and encourages early preparedness to mitigate drought impacts. The Plan borrows a concept from the fire fighting community, Incident Command System, where the organizational structure can scale itself to meet operational demands. The Plan identifies triggers to mobilize teams to accomplish objectives in each of the functional areas.

Annexes to the plan provide additional information on drought severity and impacts, guidance to water users from the Department of Health, maps of impacted areas prepared by the Arizona Department of Environmental Quality and response documents from the Arizona Division of Emergency Management. There is also an Annex for the emergency groundwater transportation permit authorized by House Bill 2478. The new law became effective on May 21st, 2003 and remains in effect until April 30th, 2004.

A web link to the Plan is available on the Arizona Department of Water Resources web site. The web address is http://www.water.az.gov/gdtf/

Background:

Governor Napolitano signed Executive Order 2003-12 on March 20th 2003 that created a drought task force. The Governor's Drought Task Force (GDTF) was charged with developing a drought plan for the State, a statewide conservation strategy and a plan to address short-term water supply issues for the immediate future. The Governor's Executive Order stated that precipitation throughout the State of Arizona during the past four years and for six of the last seven years has been significantly below normal. The lack of precipitation has significantly reduced stream flows in the interior basins and has reduced surface and groundwater supplies upon which citizens and the commerce of the State are dependent. The drought conditions affect areas throughout the State but most critically in the rural areas. The Executive Order recognized that the current drought conditions directly endanger people, property, crops, livestock, and wildlife throughout the State. In addition, economic hardship caused by drought has an impact on commerce throughout Arizona. However, actions can be taken to mitigate the effects of drought even though droughts periodically reoccur across Arizona and are a natural climatic feature of the southwest. The adverse impacts can be mitigated through proper coordination of many activities such as planning and conservation measures.

The Governor's Executive Order designated the Arizona Department of Water Resources to lead the coordination of activities of State agencies. However, the development of the long-term drought plan will include participation of all interested parties, including Native American Tribes, political subdivisions, water providers, agriculture interests, non-governmental organizations and others. The Arizona Department of Water Resources responded to the Executive Order by implementing discussions to meet the short-term water supply needs first. One of the first products of the task force is the Potable Water Plan.

Potable water needs of the State received a high priority due to the increased health risks associated with lack of potable water for daily human needs. Therefore, the Task Force is committed to developing a Potable Water Plan that provides assistance where public health and welfare is affected by potable water shortages. The Plan identifies water companies or providers that may have difficulty meeting their potable water demands this year. The Plan also identifies locations in the State where drought-related water level declines are causing, or are likely to cause, significant losses of supply for individual domestic wells.

Introduction:

Precipitation throughout Arizona has been significantly below normal during the past four years and for six of the last seven years. The lack of precipitation in the form of snow in the higher elevations has significantly reduced stream flows in the State's interior basins. Below average snowmelt has reduced or eliminated surface water sources and forced an increasing dependency on groundwater. Water supplies upon which citizens and commerce are dependent are in jeopardy of being depleted to the point of having an impact on the health and welfare of the citizens of the State. This is especially true in rural Arizona, which depends on groundwater supplies for most of its water needs. The potable water plan is focused on supporting rural areas of the State where there are few resources to mitigate the effects of drought.

Municipal water providers such as in the Tucson and Phoenix metropolitan areas have developed a variety of measures over the last twenty years to mitigate the effects of drought. Large water providers in these areas have already implemented drought response measures such as planning, water banking, and public education programs to encourage conservation.

The plan outlines a process that individuals, water providers, and political subdivisions can use to reduce the impact

of potable water shortage due to drought. The importance of monitoring drought conditions to determine the risk associated with decreased water supply is explained. A risk assessment model is described and water system vulnerabilities are listed. Water providers and political subdivisions can compare water system vulnerabilities to their own areas of concern and evaluate their risk to drought. Response mechanisms are discussed to enable political subdivisions to prepare for potable water shortages. Preparedness activities could include local water curtailment planning, familiarization with current response programs and identifying, in advance, operational mechanisms to transport water.

Specific response operations to transport potable water are discussed in the State Emergency Response Incident Action Plan attached as an Annex to this plan.

II. Climate Synopsis

The current drought in Arizona is likely to continue into next year. Arizona did receive some drought relief through rain and snow in the fall and winter, following a fairly weak monsoon season last summer, but overall the drought picture is only slightly improved.

Several years of low winter rainfall and snow have resulted in very low reservoir levels. Arizona experienced a near normal snow-pack over the late winter and early spring that reflected a dramatic increase over the same period last year. A recent USGS report, "*Water Resources Data Arizona Water Year 2002, Water Data Report AZ-02-1*" , noted that yearly discharge at five key stream flow gauging stations ranged from 29 to 57% of the median of yearly discharges.

The wildland fire season could still be very severe as it was in 2002. The fire danger outlook for the coming months predicts to be normal to above normal severity. The 1000-hour fuel moistures dropped significantly through January reaching critical levels for that time of year. However, as precipitation fell throughout the area during February and March, 1000-hour fuel moistures started showing signs of rebounding, bringing heavier fuel moisture levels back to within their normal range of 16-20 percent.

Bark beetles have and continue to increase the fire hazard potential. These insect pests not only cause severe economic damage due to destruction of timber, but the dead trees dramatically increase the potential for destructive wild-land fires. During the past two years, over 800,000 acres of Arizona's forests have been killed by these very destructive forest pests in the ponderosa pine and pinyon-juniper forests. Low tree vigor caused by several years of drought and excessively dense tree stands have combined to allow beetle populations to reach outbreak levels, about a seven-fold increase in acreage since 2001. Vulnerability to fire in Arizona's forests is likely to continue for several years as a result of the drought and there appears to be little relief in the long-range forecast. The most severe risk areas are in communities in the wildland interface where there is a shared boundary with dead trees due to bark beetle mortality. Communities that are vulnerable to wildland fire have an increased risk if a potable water shortage compromises fire fighting capability.

Drought conditions are likely to continue through next winter. Recent predictions are for the return of the La Nina in the southern Pacific Ocean. La Nina is closely associated with a cool dry winter period for Arizona. If the cool and dry winter forecast does occur next year the dangerous water supply conditions that exist in some parts of the State will be aggravated.

Objectives:

The potable water plan has several broad objectives. The first objective is to monitor climatic data and make them available to policy makers to assist in long-range decisions. Appropriate long-range decisions can mitigate the effects of drought on potable water usage in a number of ways. Proactive adoption of water conservation measures may allow water providers to meet demand during periods of limited drinking water availability.

Drought monitoring is important because the analysis of climate data is simplified from a complex set of data into a

discussion that provides a wide audience with the information that is most useful for them. The drought discussion focuses on intensity, duration, and geographic scope. It also provides a historical reference to assist in response planning and design applications.

A second objective is to create a potable water provider assessment process to collect a list of water providers that have had historical water supply problems and determine the extent of the water delivery problems that may materialize this summer. Depending on the type of water provider, there are a number of state agencies and at least one federal agency that provides regulatory oversight or technical assistance. The initial potable water assessment included the state agencies listed below. A list of water providers (municipal and private companies) was collected from each agency and evaluated using the combined staff experience of the state agencies to determine if any water supply shortages were likely for this summer.

The Arizona Department of Environmental Quality (ADEQ) provides regulatory oversight to protect water quality in Arizona. ADEQ provided a list of communities that have experienced water delivery problems in the past.

The Arizona Corporation Commission (ACC) provides additional regulatory oversight for privately owned providers and public service corporations. A public service corporation is any water provider entity other than a municipality, which furnishes water to the public for any purpose. These entities may include, but are not limited to, corporations, partnerships, individuals, cooperatives, homeowners associations, and others. The ACC provided a list of water providers that currently have curtailment tariff plans. Having a curtailment tariff plan does not automatically imply that the water provider has a vulnerability to drought related water shortage.

The Arizona Division of Emergency Management (ADEM) coordinates response to emergencies within the State. The ADEM provided a list of water providers that have historically applied for disaster assistance due to potable water shortages.

The Arizona Department of Water Resources (ADWR) currently has an internal process to collect information from private well owners that have notified the agency that their well requires deepening or if a request is filed for authorization to drill a new well due to water level changes. Private wells are reviewed and approved by local health officials to determine proper setbacks for septic tanks, and the Arizona Department of Water Resources permits the actual well drilling.

The U.S. Environmental Protection Agency also provides assistance to certain tribal water providers within Arizona, however some Indian Nations manage and regulate their own providers.

The third objective of the Plan is to develop response options that minimize the impact of potable water shortages. Although the first objective will provide water providers and policy makers with significant lead-time to allow conservation measures to be implemented, the chance of completely mitigating all water shortages through conservation measures is slight. Many parts of rural Arizona are already hauling water either out of necessity or by choice. These water users are conserving water at a remarkable level, sometimes using as little as 10 gallons per day per person *(Navajo Nation Drought Contingency Plan, 2002)*. Water conservation in some communities will have little impact on total demand. Drought-related water supply shortages in these and other communities that have implemented conservation strategies might require finding new water sources either on a temporary or permanent basis. The State Emergency Response and Recovery Plan and other federal programs may be invoked to provide water either through hauling or development of other water sources.

The Governor's Executive Order also directed the development of triggers to determine when specific conditions warrant response actions. Each functional area described below identifies a trigger that indicates a reaction to a set of drought conditions. The size and scope of the potable water organizational structure is dependant on conditions of severity. Drought monitoring is a continuous activity that is reported monthly regardless of the severity of the drought. However, the detail of the drought monitor report could vary depending on severity. The assessment group activities are invoked when conditions of drought reach a threshold that warrant ongoing vulnerability assessment of

water systems. Given the severity of the drought and the likelihood of the drought continuing, assessment of potable water should be continuous until conditions improve or the individual vulnerabilities are reduced through mitigation actions. Response systems need to be planned for to ensure a rapid operational capability.

The Plan also borrows a concept from the successful model developed from the fire fighting community's Incident Command System. As the severity of an event changes and the operational needs change, the response organization adapts to meet the needs of the incident. Adapting the response structure to fit the severity of the drought requires frequent evaluation of the drought and its impacts. Monitoring is an essential element of this evaluation. As drought conditions continue, monitoring activities should continue as well until conditions improve. Assessment and response operations could revert to maintenance level if drought conditions improve. However, it is more likely that the drought will maintain its hold on Arizona and the assessment and response activities should continue to be developed. Expanding and contracting the potable water drought plan organization to match the operational requirements reduces staff time and taxpayer expense.

III. Key Functional Areas

Monitoring

Monitor Team members may include, National Weather Service, Arizona Division of Emergency Management, Arizona Department of Water Resources, Salt River Project, the University of Arizona, the State Climatologist at Arizona State University and others.

A national drought monitoring capability already exists and there are several other drought indicators that can provide significant insight to current conditions. Other climate indices in the form of long-term prediction maps are available from a variety of sources, both government and institutional. They provide additional data and discussion forums that relate to monitoring climate conditions. There are significant resources within the state that support the climate assessment and projection process. The University of Arizona has a project funded by the National Oceanic and Atmospheric Administration (NOAA) to assess the impacts of climate variability on human and natural systems. The project, Climate Assessment of the Southwest (CLIMAS), produces a monthly report *EndInsight* that discusses the drought and its impacts. The Arizona Division of Emergency Management is a partner in the (CLIMAS) project and produces an Arizona specific drought monitor discussion monthly. The report is an analysis of climate and weather information that is collected from some of the available sources. Data is collected from the National Weather Service, National Drought Mitigation Center, and the Southwest Fire Center. Improvement in the report will be made through the integration of data that's currently not available on a regular basis.

National Drought Monitor Report is available weekly and the current State report is distributed monthly. Distribution of the report will be made to a broader audience and also made available on the Governor's Drought Task Force (GDTF) web site. Climate data by its nature is slow to change; therefore, monthly reporting is adequate. However, as national products such as the National Drought Monitor and discussion are made available, the GDTF web site will be updated. The web site is located at http://www.water.az.gov/gdtf/

Assessment

Risk is defined as a function of the frequency and severity of the event, in this case drought, and vulnerability. For the purposes of the short-term Potable Water Plan it was assumed that the frequency of the drought was equal statewide. The vulnerability analysis was conducted by collecting names of water providers that have historical occurrences of water shortages. The list of water providers was collated from each agency list discussed in the Objectives Section.

The first data source includes information collected by and from senior state staff with long-term experience in water supply, regulation, and quality oversight. Representatives from the Arizona Corporation Commission, Arizona Department of Water Resources, Arizona Department of Environmental Quality, Arizona Department of Health Services, and the Arizona Division of Emergency Management submitted names of water providers for analysis. Each

state agency prepared a list of providers that either have historical supply issues or met another qualifying condition such as application for curtailment tariffs. Once the list was developed contact was made by the Arizona Department of Water Resources with each entity to determine the extent and nature if any of their water supply problems.

Municipally Owned Water Providers

There are no municipally owned water providers currently experiencing water supply shortfalls although several rural water providers have reported areas of concern.

As noted earlier the large metropolitan areas of the state are resistant to potable water shortages due to planning, a well developed integrated infrastructure across large basin areas and effective water conservation media campaigns.

The Arizona Department of Environmental Quality provided the map locations of rural water systems that may be affected by drought and depicts the closest potential water supply sources. The ADEQ maps are listed in an annex to this plan.

A. Water Companies With Current Water Supply Problems

Four private water companies report difficulty meeting their current water needs:

Sonoita Valley, Sonoita - This company is having difficulty meeting daily demand without trucking water. The company is currently hauling water for 35 customers at a cost of $100 to $150 per truck. Integrating the system with an adjacent water provider would resolve the problem.

Bella Vista South, unincorporated area south of Sierra Vista -- This company is having difficulty meeting daily demand but believes that more proactive water conservation would have a beneficial impact. Declining water levels, increased peak demand and reduced availability of water supply are the principal reasons for concern.

Pine Water Company, Pine - The company is having difficulty meeting peak demand especially during long holiday weekends. Water hauling to meet peak demand and a more focused water conservation strategy are possible solutions.

Hunt Water Company, Strawberry - Like Pine Water Company, peak demand is an issue and a more focused water conservation strategy combined with emergency water hauling will provide sufficient water in the short term.

B. Water Providers With Potential Water Supply Problems This Summer

Beaver Valley Water	Drought related
Mt. Lemmon	Drought related
Strawberry Water	Drought related
Mayer	Drought related, peaking and infrastructure
United Utilities/East Verde	Drought related
Walden Meadows	Infrastructure related, dependent on power
Navajo Depot	Hauled water last year
Chloride	Water quantity and quality
Dolan Springs	Drought related

The second data source is the analysis of responses to a rural water provider survey recently conducted by the Arizona Department of Water Resources. Three separate surveys were distributed throughout the State. One survey was sent to 500 water providers, the second survey instrument was sent to cities and towns, and the third was sent to Counties and Tribes. To date 19 surveys were returned to the Arizona Department of Water Resources from the political subdivisions and 121 water providers have responded. Three questions in the surveys were relevant to the potable water vulnerability analysis.

The combined analysis of the questions represents a comprehensive list of underlying causes for water shortages and therefore is representative of water shortage vulnerabilities. An additional question asked if the water provider hauled water last year in response to water shortage.

The vulnerability criteria were developed from the analysis of the surveys of water providers and jurisdictions and includes the following:

Peak demand exceeds supply
Inadequate storage to meet peak demand
Inadequate pumping capacity to meet peak demand
Inadequate storage to meet long-term demand
Undersized distribution system
Inadequate water production
Infrastructure related problems/system failure
Insufficient water supply (source)
Inability to meet water quality standards

The following is an analysis of the available data as of June 17th, 2003:

Water Providers

Just over a fifth of the respondents (26) reported that the drought has had an impact on their water supply. The balance of the responses (95) indicated that they do expect to have challenges consistent with one or more of the areas of vulnerability. The most common reported vulnerability was the declining ground water levels (24), and increased peak demand (17) among water providers. Currently there are at least two water providers that reported hauling water, although four reported that hauling water is a normal part of their operation.

Political Subdivisions

The political subdivisions (19 reported) were asked if the drought had an effect on their water supply. Seven political jurisdictions reported that drought did effect their operation. The most common reason cited was reduced supply (5) and lower groundwater tables (5) followed by increased demand for potable water (4).

Individual Wells: Reported areas of concern

Small capacity domestic wells are often vulnerable to the effects of drought. In many areas of the state there are large numbers of densely located domestic wells that produce marginal volumes of water from cracks or fissures in hard rock formations. When droughts occur, the natural recharge to aquifers diminishes and water levels decline. This situation can be particularly problematic for shallow wells because water production can drop off to unacceptable levels, or wells can go completely dry. The Arizona Department of Water Resources is currently monitoring public contacts concerning water well and water supply problems that may be related to the Southwest's ongoing multi-year drought. Between April 17th and May 23rd the Department has received several reports from well owners and/or well drillers of domestic wells losing production capacity or going dry in several parts of the state.

There is some difficulty in clearly distinguishing between domestic well problems that are solely caused by the drought and problems that may be related to the impacts of other nearby wells. Wells that were reported to have gone dry in the Prescott area ranged from about 240 to 300 feet in depth and were located in hard rock areas with comparatively high densities of nearby wells. Other wells that were reported to have gone dry are located in the central part of the state near Apache Junction and Florence. Depths for these wells range from 220 to 310 feet. The impact of drought and the competition of nearby wells are potential causes of these well problems. A shallow 40-foot well was reported to have gone dry along the Santa Cruz River near Nogales. The failure of this well is undoubtedly attributable to the lack of stream flow and recharge that often occurs during the summer months along that reach of the Santa Cruz River. Applications have been filed to replace or deepen many of the wells mentioned.

The ADWR anticipates there may be many more reports of drought-related domestic well problems as the summer season progresses. These reports will be monitored and analyzed along with available water level data to help the Department identify other vulnerable areas of the state where drought-related water level declines are likely to cause significant losses of supply for individual domestic wells. This analysis will help form the basis for both short-term relief efforts and long-term plans and strategies to deal with this important concern.

The map on page 13 depicts the domestic wells that have been reported to have gone dry since the end of May 2003.

Trigger

The potable water providers identified as being previously reported or have potential vulnerabilities should be routinely assessed throughout the summer to anticipate any response actions that may be necessary. The Arizona Department of Water Resources, Arizona Corporation Commission, Arizona Department of Environmental Quality, Arizona Department of Health Services and the Arizona Division of Emergency Management will meet on a regular basis to share assessment data and evaluate any other water providers that have the potential to experience water shortages. The Arizona Department of Water Resources staff has established routine contact with the water providers that are currently experiencing water delivery challenges to provide a constant assessment profile.

Locations of Domestic Wells That Have Been Reported To Have Gone Dry Due to Drought Conditions (Reports compiled by ADWR from 4/03 to 5/03)

MAP HERE

Response:

Response to a potable water emergency should include a concentrated effort to reduce the demand for potable water through conservation measures. The Arizona Corporation Commission has a curtailment plan format that has been used for a number of private water companies that describes specific actions that might mitigate the effects of the shortage that can be taken in advance of an emergency. However, conservation measures may not be successful if water use is already limited to essential uses or the water supply is a fraction of the volume needed. In some cases, drought related potable water shortages might only be alleviated through the augmentation of the water supply, generally through transfer or hauling water.

Prior to hauling water, regulatory considerations should be considered. The Arizona Corporation Commission requires

a notification process for private water companies that are under their jurisdiction. In addition, the state Groundwater Code prohibits most transfers of groundwater from basin to basin. However, the Governor signed legislation this year (HB 2478) that authorizes the Director of the Department of Water Resources to approve temporary inter-basin transfer of groundwater outside the Active Management Areas under certain conditions. The legislation expires on April 30, 2004. The Arizona Department of Water Resources has developed a drought emergency groundwater transportation permit application process. The permit application process is provided in an annex to this plan.

The State's surface water laws protect the use of surface water. A surface water claim or right authorizing the use of the water at the location is requirement of either State or Federal law.

Where conditions result in a lack of potable water either due to infrastructure failure or drought related water supply limitations, response actions can be taken to assist political subdivisions. Where the health or welfare or the citizens of the State is a concern, the Governor has the authority to declare an emergency that authorizes the State Emergency Response and Recovery Plan to be invoked. Under the State plan, political subdivisions are eligible for reimbursement of 75% of their costs to haul water. Jurisdictions that seek to use this authority should contact their local emergency manager or contact the Arizona Division of Emergency Management for guidance. An Annex to this plan includes a checklist for local jurisdictions that may require assistance.

Political subdivisions that anticipate needing assistance based on risk assessments against the vulnerability profile should contact their county emergency response program coordinator to begin to identify operational needs.

The Arizona Division of Emergency Management will notify the State assessment team to enable each State agency with specific responsibilities in the State Emergency Response and Recovery Plan and the Potable Water Incident Annex to complete assignments. Early assessment and frequent communication with drought affected political subdivisions strongly encouraged.

Annex: Governor's Executive Order
Annex: Current Arizona Drought Discussion
Annex: State Emergency Response Incident Action Plan
Annex: Arizona Department of Health Services: Drought Information Sheets
Annex: Drought Emergency Groundwater Transportation Permit Application

Annex: Governor's Executive Order

(included in Appendix I)

Annex: Drought Discussion

Arizona Drought 2003

Arizona Division of Emergency Management
1 April 2003

Drought Continues, Despite Near-Normal Winter Rains
Drought and Wildland Fire Concern Continues

The current drought in Arizona is not over, and will probably not be over by next year. We have gotten some relief from rain and snow in the fall and winter, following a fairly weak monsoon season last summer, but overall the drought picture is only slightly improved.

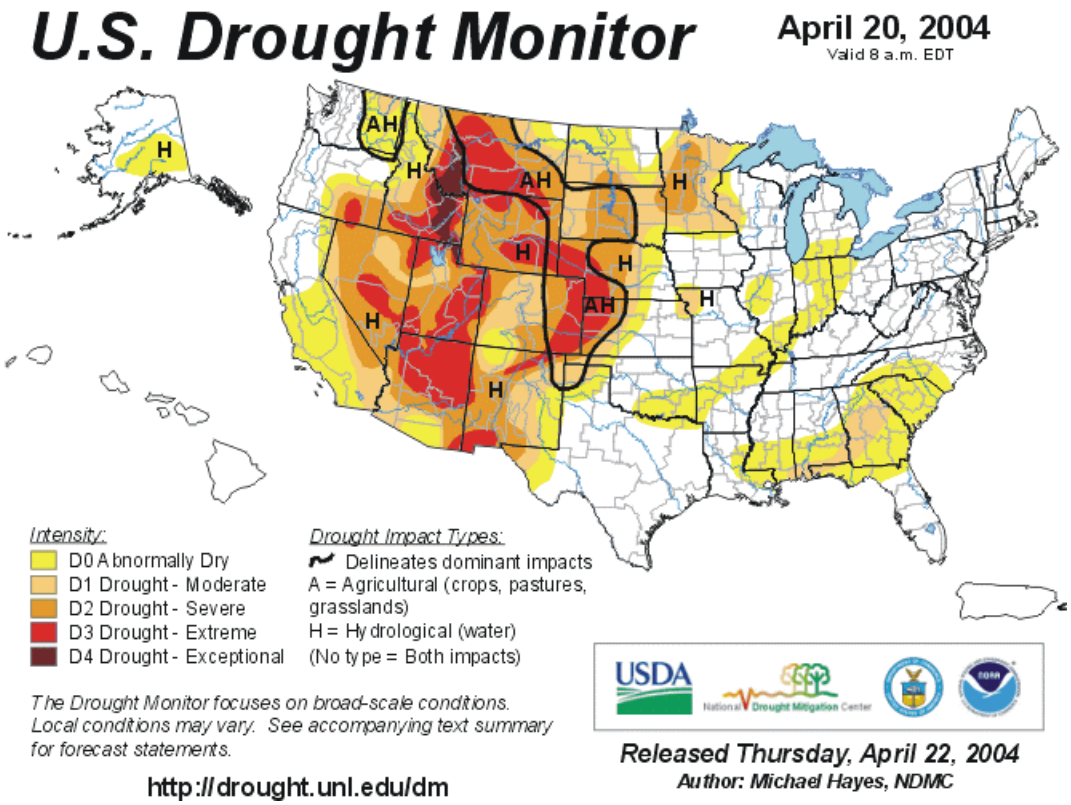
El Niño may help with late winter precipitation, but won't be able to break the drought. The moderate El Niño condition that has developed in the tropical Pacific Ocean is likely in its last 1-2 months before weakening to neutral levels. Above normal precipitation is expected in Arizona this spring, but with lingering above normal temperatures. It will he a good start towards recovering from the drought, but even so, the current moisture deficits are so severe that it will not end the drought.

Very low reservoir levels remain as a result of several years of low winter rainfall and snow. Arizona experienced a large snow-pack over the last several weeks with dramatic increases over the same period last year. (Upper Salt River Basin from 31% last year to 92% now; Central Mogollon Rim from 28% to 99% now) Variable stream-flow levels are predicted for key streams in Arizona. In that regard, in the Verde River and Tonto Creek, the forecast calls for above median stream flow levels through May. All other major streams in key watersheds, however, can expect below median flows through springtime.

The wildland fire season could still be very severe again in 2003.
The fire danger outlook for the coming months is predicted to be normal to above normal. 1000-hour fuel moistures dropped significantly through January reaching critical levels for the time of the year. However, as precipitation fell throughout the area during February and March, 1000-hour fuel moistures started showing signs of rebounding, bringing heavier fuel moisture levels back to within their normal range of 16-20 percent.

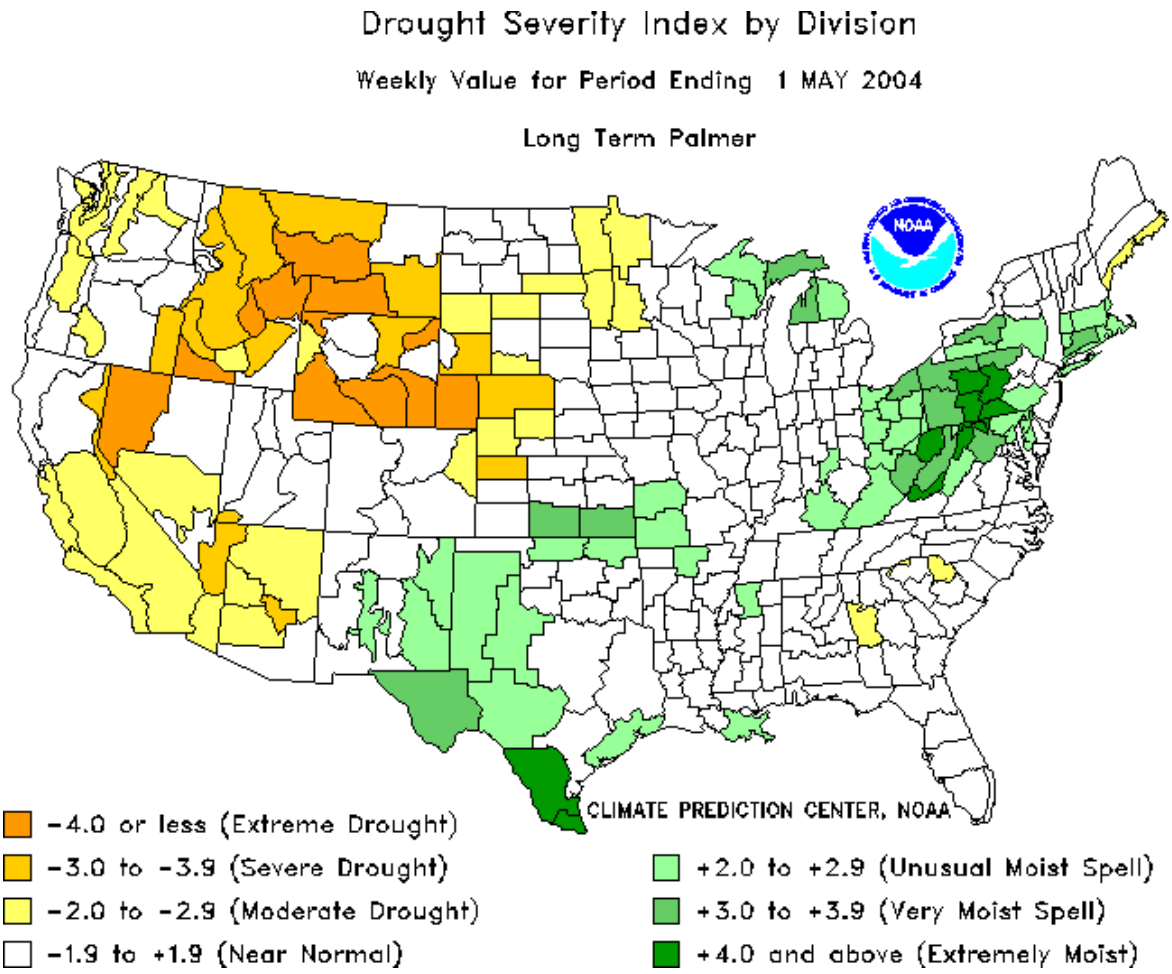
Bark beetles are causing severe economic damage and worsening the fire hazard.
Another consequence of the drought is that well over 600,000 acres of Arizona's forests have become infested with bark beetles, a very destructive forest pest native to ponderosa pine and pinyon-juniper forests. Low tree vigor caused by several years of drought and excessively dense stands of trees have combined to allow beetle populations to reach outbreak levels, about a 7-fold increase in acreage since 2001. This insect pest not only causes severe economic damage due to destruction of timber, but the dead trees seriously increase the potential for wildland fires.

U.S.



Drought Monitor *April* 1, 200

Two widely used drought measures, the U.S. Drought Monitor (above), and the Palmer Drought Severity Index (below), differ somewhat in the Arizona drought picture, but both of them show moderate to extreme drought conditions continuing throughout most of Arizona.



Palmer Drought Severity Index

The Palmer Drought Severity Index does not indicate as much of the state to be in severe or extreme drought as the US Drought Monitor does, but it nevertheless indicates a drought persisting in Arizona.
The Palmer Index was developed primarily for the Midwest and the eastern parts of the country, and does not necessarily give the most accurate assessment of Southwestern drought conditions.

Arizona Reservoir Status - Early-April 2003

Colorado River Reservoirs	Storage (1000 acre-ft)	% Full	Year Ago
Lake Powell	12,444	51	70
Lake Meade	16,826	64	75
Total	31,496	60	73
In-State Reservoirs			
Salt River	769	38	36
Verde River	199	69	22
Total Salt/Verde System	968	42	34
San Carlos Reservoir	42	5	8
Lake Pleasant *	630	74	(Approx.) 70

*(Lake Pleasant functions as a temporary storage and distribution facility for CAP water from the Colorado River. Its level is not indicative of the in-state watershed conditions.)

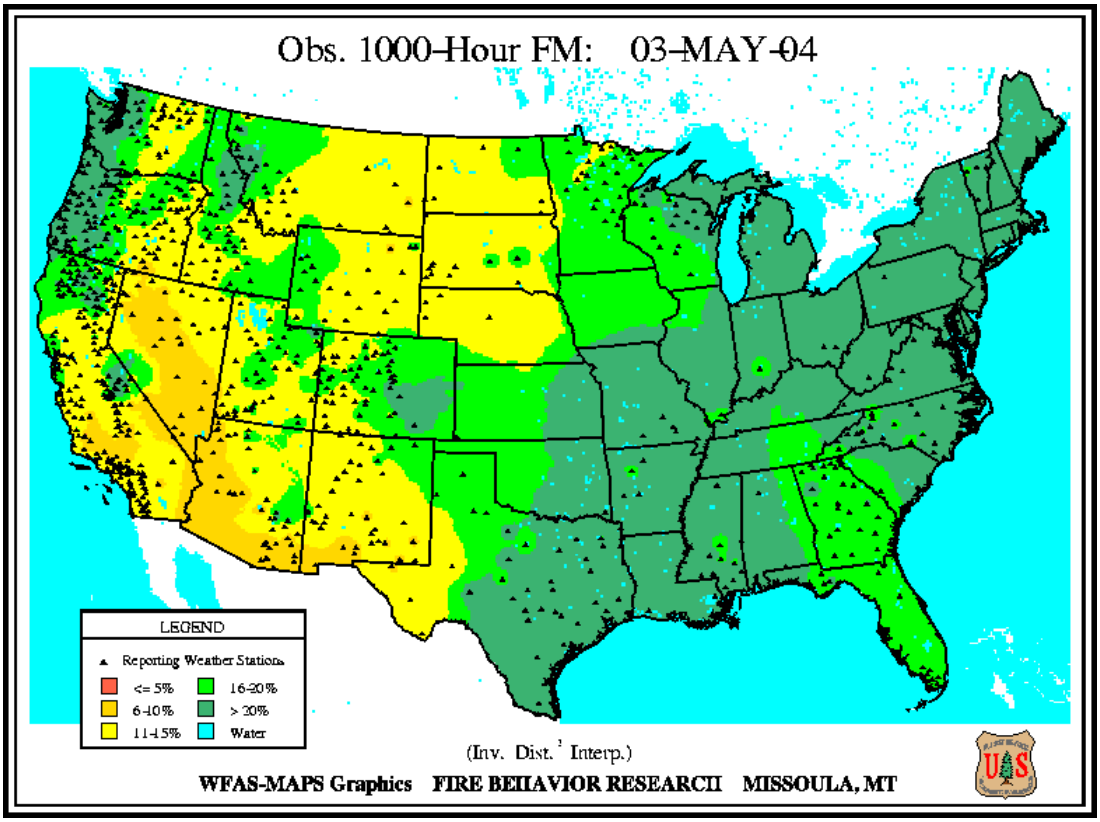
Reservoirs inside the state are in generally better shape than they were a year ago, yet the large reservoirs along the Colorado River have continued to drop relative to last year. As of the 1st of January, the Salt River Project has cut water allocations to all of its clients by one-third (from 3 acre-feet per acre to 2 acre-feet per acre), as a water conservation measure. This will make it necessary for clients to procure more water from other more costly sources, such as the Central Arizona Project.

SRP permitted to fill Lake Roosevelt.
SRP was working with the US Fish and Wildlife Service on a Habitat Conservation Plan (HCP) for the Southwestern Willow Flycatcher near Roosevelt Lake. The Fish and Wildlife Service have approved the HCP, and the reservoir system is currently at 38% capacity. However, it has recently been discovered that there are also flycatcher populations nesting near the shoreline of Horseshoe Reservoir, and a similar HCP must be approved for Horseshoe before that reservoir can be filled.

The NRCS Phoenix office reports the following: Good rainfall in the last half of February, and through March, helped to bring precipitation levels in key watersheds closer to average. In that regard, the Little Colorado and Verde River Basins along with the Central Mogollon Rim are now at 100% of average (precip.). Other watersheds including the Salt, San Francisco, and the Upper Gila River Basins also benefited from the winter moisture, but lag behind average at this time. Especially dry for the ranchers and farmers, are the areas in the proximity of Safford, Wilcox, Sells, Douglas, and the Navajo Nation. All other parts of the State continue to report very dry conditions.

Wildland Fire Season May Be Severe in 2003. Larger size forest fuels condition will be critical factor for fire season.
1000 hour fuel moistures are expected to remain at near normal levels (i.e. 16-20 percent) through April. By late May and June, it is expected that fuel moisture will drop to near record low values, thus suggesting an increase of available fuels, and it is these fuels that have the potential to create very extreme “crown fires” that propagate from treetop to treetop, and are extremely destructive and dangerous.

The map shows the conditions of these fuels, referred to as “1000-hour” fuels, meaning that it takes them about 1000 hours (around 40 clays or so) to change their moisture content significantly in response to changing weather conditions. These larger fuels are in marked contrast to the smaller “fine” fuels like grass, leaves, and pine needles, which can change their moisture content in a matter of only a few days or hours.



When the 1000-hour fuel moisture contents are down as low as 10-15%, the potential for very large fires becomes extreme. As the map shows, the moisture content of these larger fuels throughout much of the state is consistently 16-20%. This is a relatively normal condition for April. These fuels will dry out to very low levels by late spring or early summer.

The spring grass crop may be drying out earlier than normal, if the climate forecast for above normal temperatures for the spring through summer is correct. There is a very large amount of dead fuel in the brush fields at mid-elevations throughout the state. Severe drought-related mortality has produced these dead fuels, including manzanita, pinyon pine, and oaks. Bark beetle infestations have also contributed to large amounts of dead ponderosa pine. (See map on next page.)

The most likely scenario for the spring/summer fire season in the Southwest Area features a continuation of normal to above normal temperatures and above normal precipitation early on becoming more normal later on. Fire danger is currently within normal range. The current situation coupled with the weather outlook should result in fire danger to be slightly above normal for elevations below 8500 feet by May. Large acreage fire potential will be above normal from late May through early July leading to extended attack. Mop-up will be much more critical due to the spotting potential and increased risk of escape.

The worst-case scenario entails a dramatic drop off in precipitation occurrence through the spring with a worsening of the drought conditions currently being experienced across the Southwest Area. This scenario assumes that no further significant precipitation occurs until the onset of the summer monsoon season. The result of this forecast coupled with current conditions will produce extreme fire danger conditions for up to 3 weeks during the month of June. Large acreage potential will be very high with fires that escape initial attack and quickly transition from surface fires to crown tires. Any escaped fires will be extremely resistant to control, more likely to transition to plume dominated and exhibit the potential for long range spotting.

As in 2002, the fire season this year has the potential to be extremely severe, with the potential for development of very dangerous conditions across the state. It may well take several years for the Arizona forests and woodlands to recover from the drought, even if we get adequate or even abundant rainfall, because trees that have been drought-stressed for several years are not as able to take advantage of rainfall when it does occur as well as they can when they have not been under prolonged drought stress.

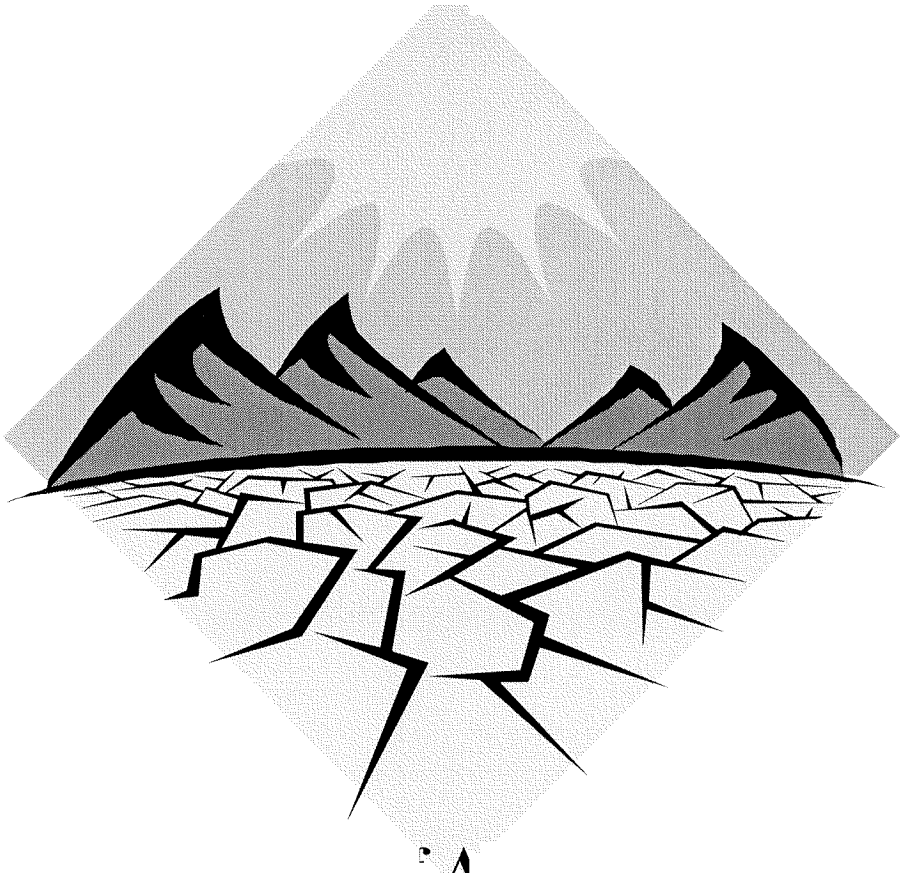
Alex McCord, Situation Analysis, ADEM, (602) 231 6211, mccorcla@tlcni.state.az us

Bark Beetle Outbreak
2002 Aerial Detection Survey

Map Here

Annex: State Emergency Response Incident Action Plan

Arizona Drought Emergency 2003



State of Arizona
Emergency Response
Incident Action Plan
Operational Period:

04/08/2003 to 07/31/2003

Background
May 20, 2003

For the fourth year in a row, Arizona has experienced well below normal rainfall. Out of the last seven years, six have been below normal, some of them extremely dry. Watershed snowpack levels are very low, generally below 20% of normal, leading to a streamfiow forecast of much below median for all of the streams and rivers in Arizona. This year the rnainstem Colorado River is also forecast to provide only *50%* of its normal inflow into Lake Powell. All the major reservoir levels in the state are below normal, including the largest reservoirs along the Colorado River.

The very dry conditions have increased the likelihood that there will be water supply problems in the smaller communities and a shortage of rangeland feeds for cattle and other livestock. The potential for a severe wildland fire season has also increased. No particular water supply problems are anticipated in the major metropolitan areas and the large farming districts because of the availability of water from the Salt River Project, Central Arizona Project, and well-developed groundwater systems.

Fire occurrence and fire behavior in the lower elevation perennial grasslands in the southeastern part of the state has been above normal this spring, an early indicator of a potentially very difficult fire season. Fire activity has not been particularly high in the rest of the state so far, primarily because the very dry winter conditions have not allowed any significant grass cover to develop, except in the southeast part of the state. Where fires have started in the northern part of the state, they have spread much more rapidly than they normally do this time of the year.

High temperatures and low precipitation amounts are likely to continue throughout the spring and early summer. The larger size classes of forest fuels (branches and downed logs) in the higher elevation timber and brush country are currently in a very dry condition, and are almost certain to remain dry even if some precipitation does develop. The smaller size fuels (twigs, leaves, grass and brush) will be drying out over the next few weeks, and as that develops it is anticipated that the fire conditions in the forests and woodlands will become very active until the monsoon season rainfall is well established, probably sometime around midsummer. Such dry springtime conditions do not necessarily lead to a severe fire season, but they do indicate that planning for a severe fire season is warranted.

Arizona Drought Emergency 2003

(Emergency Response)

Time Prepared: 1300 hours, May 20, 2003

Operational Period: April 8, 2003 through July 31, 2003

General Incident Objectives

1. In cases where public health is compromised by drought, provide the management structure and mechanisms to provide potable water for human consumption.

2. In cases where public health is compromised by drought, provide Governor's Emergency fund reimbursements to political subdivisions.

3. Facilitate requests for assistance from Arizona's Native American nations through the Federal Government.

4. Anticipate future operational needs such as potable water, wildland fire and agriculture. Plan logistical requirements to support these needs.

5. Produce situation reports. Use E-Team to note current and projected drought status and provide detailed operational status by county.

Attachments:

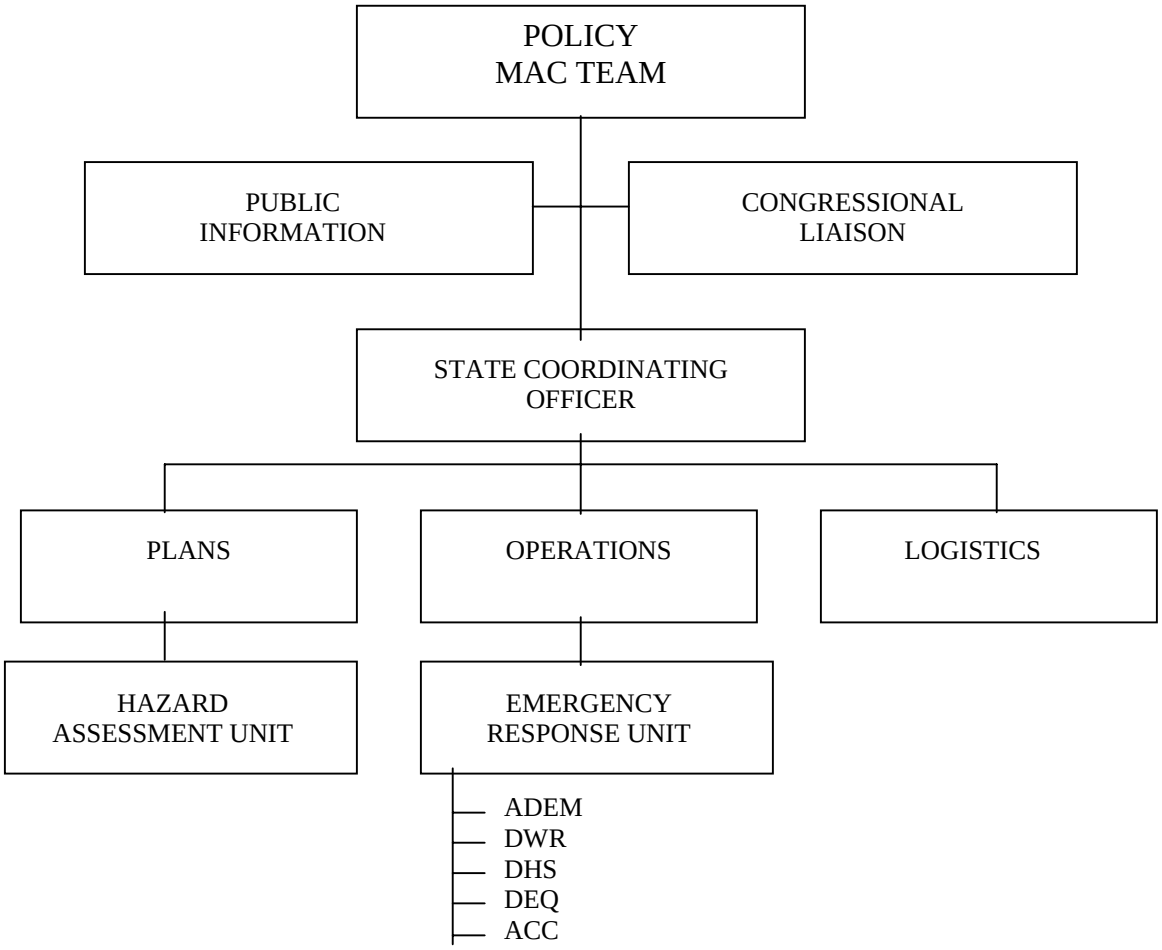
1. Organizational Chart

2. Description of SEOC Functional Groups

3. State Response Priorities

4. Assignment Lists (Agriculture, Potable Water, Wildlife Fire)

ARIZONA DROUGHT EMERGENCY 2003
Incident Management Team



Arizona Drought Emergency 2003

(Emergency Response)

Incident Management Functional Groups

Drought operations will continue as the situation dictates and at the direction of the Director, ADEM. Operations will be comprised of the following functional elements:

POLICY GROUP: This group is responsible for the strategic direction of state level emergency operations. Performs or supports the command function and may include representation from other state agencies or multiple jurisdictions. Mutual aid liaison is established here. Strategic direction is articulated from the Policy Group. Also known as the Multi Agency Coordination Team or MAC.

PUBLIC INFORMATION OFFICER: The Public Information Officer (PIO) is responsible for processing and disseminating emergency public information to the media.

PLANS GROUP: This group coordinates elements of information to provide the focus for analysis relative to the incident. This group is responsible for monitoring and reporting the current situation status, as well as projecting and planning for possible incident developments in the future. This group has the primary responsibility for the production of action plans and to work directly with other staff elements in order to coordinate operational requirements.

OPERATIONS GROUP: This group is responsible for state tactical command, coordination, and incident response assets. Tactical level liaison of mutual aid is accomplished by this group. The Operations Group monitors and assesses current operational conditions, short-falls, and unmet human needs. Depending on mission requirements, the Operations Group may include Public Safety, Fire/Rescue, Mass Care, and Public Works and Engineering Branches.

LOGISTICS GROUP: This group coordinates personnel, resources, communication augmentation, supplies, procurement, etc., required b support State agency response. The elements of the Logistics Group are: Information Management, Resource Support, Communications, SEOC Support, and Fiscal Services. Request for assets, whether internal or external, are validated and processed by this group. The Logistics Group handles the financial aspects of an emergency operation as well as maintaining the message center and documenting the need for/use of both human and material resources.

Arizona Drought Emergency 2003

(Emergency Response)

State Response Priorities

If state assets are required, their response will be coordinated between ADEM and the county emergency operations centers. Response priorities will be determined by the degree of threat to human life, the protection of property and maintenance of economic stability in Arizona. County emergency operations centers should consider the following before requesting state resources:

1. Have city, county, and mutual aid resources been exhausted?
2. What resource is the most appropriate for the mission?
   - → Are other local and county assets available?
   - → Which resource has the best response time'?
   - → What is the most cost/effective resource?
3. Given scarce resources, what is in the best interest of the state-wide mission?

Five Ws

Prior to the deployment of state resources, the following must be answered:

1. Who needs the resource?
   - → Identify the point of contact and means of communication.
2. What is needed? What is the nature of the mission?
3. When is the resource required'?
4. Where is the resource needed?
5. Why is this specific resource required? Are there other options?
   - → Explain why this is the most appropriate resource for the mission.
6. How is the resource to be delivered'?

Arizona Drought Emergency 2003

(Emergency Response)

Assignment List
Hazard Assessment Unit

McCord/Parks, ADEM

Operational Period: April 8, 2003 through July 3 1, 2003

SPECIAL INSTRUCTIONS:

1. Monitor the development of weather and climate conditions affecting the drought situation throughout the operational period.

2. Maintain liaison with appropriate state and federal agencies charged with collecting, analyzing, and disseminating information related to weather and water supply.

3. Analyze available information to assess the likelihood of intensification or lessening of drought conditions in Arizona, and on their potential impact on the state.

4. Provide periodic drought situation reports and provide spot situation reports when needed.

Prepared by:

Approved by:

Arizona Drought Emergency 2003

(Emergency Response)

Assignment List
Potable Water Emergency Response Unit

Operational Period: April 8, 2003 through July 3 1, 2003

SPECIAL INSTRUCTIONS:

1. Monitor community-level potable water status throughout the state.

2. Conduct periodic checks with county emergency managers to identify communities with potable water shortages.

3. Maintain a situation map noting current community status.

4. Prepare community status reports for addition to the drought situation report. Include
   → Does the community expect to run out of potable water? If so, when?
   → What remedial actions are in progress?
   → Can the community/county acquire supplementary potable water?
   → Will state emergency assistance be required?

5. Provide preliminary technical support to counties and communities. Route communities to appropriate support organizations.

6. Coordinate water shortage recommendations with ACC, ADEQ, ADHS, ADWR.

7. In cases that qualify for state emergency assistance, the counties will identify and coordinate the delivery of potable water to affected communities through commercial water companies.

8. If commercial water providers become unavailable, AZ ARNG resources will be utilized as a last resort.

See Appendix A for further details of the Potable Water Emergency Response Operating Procedures.

Prepared by:

Approved by:

ADEM Initial Potable Water Assessment Checklist

(Name of Political Subdivision)

The Governor's Emergency Fund will not be used to provide water for livestock or irrigation of crops. The Fund may be used to provide potable water for human consumption. All applicable local, state and federal policies and laws must be followed. Prior to requesting state assistance, it is our recommendation that the following measures he taken as a minimum.

1.

Has public health been compromised?	Yes / No
Has a public health emergency been declared?	Yes / No
Which public health department declared the emergency?	County / State
Date of declaration:	

2.

Have water rationing and other prudent conservation measures been implemented?	Yes / No
Describe actions taken and date initiated. Provide examples of actions.	
Action:	Date:
Action:	Date:
Action:	Date:

3.

Do you have a water curtailment plan approved by the Corporation Commission?	Yes / No
Date Approved:	

4.

What steps have been taken to restore normal water delivery methods?	
Were permits required and obtained?	Yes / No

5.

In what way has this event exceeded both county and local ability to respond? (Please provide copy of budget.)
Financial:
Physical Resources:

6.

What is the anticipated duration of this potable water emergency?

ADEM Initial Potable Water Assessment Checklist (Continued)

7.

Is this a new problem, reoccurring problem or a seasonal problem? Please describe.

8.

What Mutual Aid alternatives have been explore and/or exhausted?
Who was contacted and when?

9.

Have you contacted any of the following State Agencies for assistance?

Agency	Type of Assistance	Representative	Date Contacted	Assistance Provided
AZ Corporation Commission (ACC)				
AZ Dept. of Environmental Quality (ADEQ)				
AZ Dept. of Health Services (ADHS)				
AZ Dept. of Water Resources (ADWR)				
Other				

Signature:
Applicant Agent _____ Date: _____

Title: _____

ADEM/ADWR Use Only

ADWR Policy recommendation to the Governor _____

_____ Date: _____

**** Please attach all documentation supporting the items listed above and provide copy of budget. ****

County Role

The county is responsible for:

1. Implementing the most cost/effective solution.
2. Managing the distribution of water (if required).
3. Contracting with commercial providers (if required).

Annex: Arizona Department of Health Services Drought Information Sheets

Drought Information sheet:

Food Establishment Information for Drought-Induced Water Outages

Arizona Department of Health Services

Summer 2003

Can I keep my food establishment open when our water system has an outage?

Yes. In most circumstances you can still operate your food establishment if your water system has an outage. However, you will need to take some measures to ensure that the food remains safe.

What measures do I need to do to take to keep the food safe?

Basically, you will need to take the same measures that temporary food booths use to ensure food safety at special events:

- Have enough bottled water on-hand for your food handlers and eat-in customers to wash their hands.
- Have hand sanitizers available for use.
- Use gloves during food preparation.
- Use single-service disposable utensils, plates etc. for food service.
- Limit your food processing to simple menu items that don't require using utensils and pans that need to be cleaned.
- Have access to a portable toilet.

Do you have specific guidance that describes exactly what to do?

The Arizona Department of Health Services has a specific guidance document that describes how to safely operate your food establishment during a community water outage. The guidance is posted on our website at http://www. hs.state.az.us/phs/oeh/fses/index.htm

You can also get additional information from the Office of Environmental Health at 1.800.367.6412.

Drought Information sheet:

School Management
During Drought-Induced Community Water Outages

Summer 2003

Can I keep my school open when our water system has an outage?

Yes. In most circumstances you can still operate your school if your water system has an outage. However, you will need to take some measures to ensure that the children's environment remains healthy.

What measures do I need to do to take to keep the children healthy?

- You will need enough bottled water for the children and staff to drink. One liter of bottled water per person per day will be needed, more during hotter temperatures.
- If you use evaporative cooling an alternative source of climate control will be needed to avoid heat related illnesses. If no alternative is available, dismissing school should be considered.
- You will need to have some portable toilets available for the children and staff. Having one portable toilet for every 100 persons is usually adequate.
- Have hand sanitizers available for children, staff, and cafeteria workers.
- Have enough bottled water on-hand for your cafeteria workers to wash their hands.
- Use gloves during food preparation.
- Use single-service disposable utensils, plates etc. for food service.
- Limit your cafeteria food processing to simple menu items that don't require using utensils and pans that need to be cleaned.

Do you have specific guidance that describes exactly what to do?

The Arizona Department of Health Services has a specific guidance document that describes how to safely operate your school during a community water outage. The guidance is posted on our website at http://www.hs.state.az.us/phs/oeh/fses/index.htrn

You can also get additional information from the Office of Environmental Health at 1.800.367.6412.

Drought Information sheet:

Food Establishment Operation Guidelines During a Drought-Induced Water Outage

Arizona Department of Health Services

Summer 2003

Handwashing

Equipment

During a drought-induced water outage, a hand wash station is needed for employees and customers at all Food Establishments.

- A minimum of 5 gallons of warm water (95-105°F) in an insulated container with a spigot or spout (i.e. igloo® or cambro®).
- A container for the waste-water, which must be disposed of into an approved sewer or wastewater system.
- Hand soap and paper towels (sanitizers do not replace hand washing).
- A heating device such as a coffee machine, grill or hot plate.

Procedures

Hands and exposed portions of arms should be washed with soap and water. Vigorously rub hands and arms together for at least 20 seconds and thoroughly rinse with clean water. Employees should pay particular attention to the fingertips, the areas underneath the fingernails and between the fingers.

Handwashing Frequency

- Wash hands after touching your face or other parts of the body.
- Wash hands after using the portable toilet.
- Wash hands after coughing, sneezing, using a handkerchief or disposable tissue, using tobacco, eating or drinking.
- Wash hands when switching between working with raw food and working with ready-to-eat food or when engaging in activities that contaminate the hands.
- Hands should be washed at least once per hour.

Utensil & Equipment Washing

Food processing should be limited to simple menu items that don't require using utensils or pans that need to be cleaned. If utensils and equipment are used in food and beverage service, the utensils and equipment are required to be washed and sanitized. The proper sanitation requires the use of a four-step procedure.

- Three adequately sized containers should be set-up.
- The first container is used for washing and contains hot water and dish soap.
- The second container is used for rinsing and contains hot water.
- The third container is used for sanitizing with cool water and 50-100 parts per million (PPM) of chlorine bleach. Use one capful of bleach for every five gallons of water.
- You should have test strips available to test the level of chlorine in the water.
- After completing the three steps, all utensils and equipment must be air-dried.
- Change the water and replace the soap and bleach in the containers frequently to keep the process effective.

Food Safety

Food Source

- All food and beverages must be from an approved source.
- Food prepared in a private home may not be used, nor offered for human consumption in a Food Establishment during a water outage. Homemade food products cannot be used or provided to customers in the establishment.
- All packaged foods should be properly labeled.
- Food items should be limited to those that require limited preparation during a drought-induced water outage in a Food Establishment. Foods requiring extensive hand contact or multiple steps are discouraged.
- Ice that is consumed or contacts food should be only in chipped, crushed, or cubed form. The ice should be stored in single-use food grade plastic bags, or wet-strength paper bags filled and sealed at the point of manufacture. It should be held in these bags until it is dispensed in a way that protects it from contamination.

Food Protection

- Gloves or utensils should be used to prevent bare hand contact with ready-to-eat foods such as breads, tortillas, chips, produce for juicing, and garnishes.

- Non-latex, single use gloves must be used. Utensils, wax paper or foil may be used as well. Remember to wash hands before putting on gloves. Change gloves when switching task or when gloves become dirty or worn. Gloves must be worn when employees have sores, burns, and/or bandages on their hands.
- All condiments should be dispensed from disposable squeeze bottles or individual packets.

Portable Toilets

In the event of a water outage, the food establishment must have access to portable toilets for employees and eat-in customers. Unless local regulations are more stringent, the food establishment should have access to:

- One portable toilet for the first 100 people and 1 portable toilet for each additional 100 people, or portion thereof.
- Portable toilets should be located within 200 feet of the food establishment.
- Collection, storage and treatment of sewage as required by the Arizona Department of Environmental Quality under 18 A.A.C. 8, Article 6 and 18 A.A.C. 9, Articles 7 and 8.

Length Of Operation During A Drought-Induced Water Outage

The food establishment cannot operate during a drought-induced water outage for more than 14 consecutive days unless state or local emergency procedures are in effect.

You can also get additional information from the Arizona Department of Health Services at 1.800.367.6412.

Annex: Drought Emergency Groundwater Transportation Permit Application

Arizona Department of Water Resources
Water Management Division
500 N. 3rd Street Phoenix, Arizona **85004**
(602) 417-2470 (800) 352-8488
www.water.az.gov

Application to Transfer Water Between Groundwater Basins For Emergency Drought Relief

Fill in each section completely and accurately. Please print using black ink. Please attach all required documentation to the end of this application form.

Date of Governor's Declaration of Emergency Due to Lack of Precipitation or Water Shortage:

_____

Section 1: Source **of Groundwater to be Transferred between Groundwater Basins:**

Well Registration Number_____ If more than one well will be utilized, provide well registration numbers for all additional wel1s_____
_____

Public Water Supply system identification number (if applicable) _____

Is the well from which the transported groundwater will be withdrawn located within the incorporated area of a city or town? ☐ Yes ☐ No
If the answer is yes, applicant must attach an original letter from the city or town on that entity's letterhead stating that the city or town approves of the withdrawal of groundwater from the well(s).

Specify the city or town from which groundwater is to be transported _____

Is the well from which the transported groundwater will be withdrawn located within the boundaries of a political subdivision, established pursuant to A.R.S. Tile 48, Chapter 17 or 19 (e.g., an irrigation district agricultural improvement district, or water conservation district)? ☐Yes ☐ No
If the answer is yes, applicant must attach an original letter from the political subdivision on that entity's letterhead stating that the political subdivision approves of the withdrawal of groundwater from the well(s).

Specify the political subdivision(s) from which groundwater is to be transported _____

Is the well from which the transported groundwater will be withdrawn located within one county and the water will be transported to another county? ☐Yes ☐No
If the answer is yes, applicant must attach an original letter from the county from which the water will be transported on that county's letterhead stating that the county approves of the withdrawal of groundwater from the well(s).

Specify the county from which groundwater will be transported _____

Specify the county to receive the groundwater _____

Specify the method by which the groundwater will be transported _____

Section 2: Location and Use of Groundwater Transported Between Basins

Specify the uses to which the groundwater transported from the above location will be put:

Domestic water supply ☐ Municipal water supply ☐ Stockwater ☐

If the transported groundwater is planned to be used for domestic water supply for single residences, specify the locations of each residence to be so supplied. Use continuation sheets for additional residences. List the name, address, and telephone number of the landowner, as well as the county tax assessor's parcel identification number for each residence and the residence address if different than the landowner's address.

I,ANIDOWNER	CONTACT PERSON LIVING AT RESIDENCE
ADDRESS	RESIDENCE ADDRESS
CITY, STATE, ZIP CODE	CITY, STATE, ZIP CODE
TELEPHONE E	COUNTY TAX ASSESSOR'S BOOK, MAP, PARCEL NUMBER

If transported groundwater is to be used for municipal water supply, specify the name of the water provider, the public water supply identification number, address, telephone, and a contact person

WATER PROVIDER NAME	CONTACT PERSON
ADDRESS	TELEPHONE
CFFY, STATE, ZIP CODE	PWS ID#

If transported groundwater is to be used for stockwatering, specify the legal description and ownership of the land where the water is to be used.

TOWNSHIP RANGE	SECTION	160 ACRE QUARTER	40 ACRE QUARTER	10 ACRE QUARTER
LANDOWNER NAME AND ADDRESS				
CONTACT PERSON (IF DIFFERENT FROM LANDOWNER) AND TELEPHONE NUMBER				

Is the area to which groundwater is to be withdrawn or transported located within an Active Management Area? Yes ☐ No ☐

Does the county, city, town, or other political subdivision within which the transported water is to be used have in place an emergency conservation plan sufficient to prevent nonessential use of the groundwater?
Yes ☐ No ☐

Applicant must attach a copy of the conservation plan.

CERTIFICATION

As the responsible party, I certify that the Governor of Arizona has declared an emergency due to drought, lack of precipitation, or water shortage in my area, and that an emergency need exists to transport groundwater for interim water supplies for humans and/or stockwatering. I further certify that written consent has been obtained from all relevant parties, and that a water conservation plan is in effect for my area. I further certify that the transported groundwater shall not be utilized to subsidize or augment insufficient water supplies resulting from continued growth or deficient base water supplies for the area. I further certify that transportation of the groundwater shall cease upon expiration of the permit period or upon notification that the Director has determined that the transportation of groundwater is no longer necessary, whichever comes first, unless the permit is renewed.

I certify that all the information in the above application is true, complete and correct to the best of my knowledge.

_____ _____

SIGNATURE **DATE**

DROUGHT EMERGENCY GROUNDWATER TRANSPORTATION
PERMIT APPLICATION PROCESS

House Bill 2478 allows transportation (hauling) of groundwater between groundwater basins outside of Active Management Areas (AMAs) in the event of a drought emergency resulting in a water shortage. This new law became effective on May 21, 2003, and will remain in effect until April 30, 2004. Several conditions must occur before the transportation of groundwater between basins (which is normally not allowed under statute) can occur. Most importantly, the Governor of Arizona must first declare an emergency due to lack of precipitation or a water shortage pursuant to Arizona Revised Statutes (A.R.S.) § 35-192.

The other requirements that must be met are outlined on the attached application form. Briefly summarized, the applicant must identify the source of groundwater. Then the applicant must identify where the groundwater to be transported will be used, as well as the specific uses to which the water will be put. Transportation of groundwater between groundwater basins in a drought emergency is only allowed to supply people (single residences or water providers) or animals such as livestock. Transportation of groundwater between basins is never allowed to shore up insufficient supplies resulting from continued growth or base supplies that were deficient to begin with. Pipeline transportation is not allowed; only motor vehicles or trains can haul the water.

Before withdrawing the groundwater from a basin for transportation, the applicant must identify the well(s) to be pumped. The well(s) must be in existence on the date of the Governor's declaration of an emergency. If the well(s) are located within the incorporated boundaries of a city or town or within the boundaries of a political subdivision established pursuant to A.R.S. title 48, chapters 17 and 19 (which deal with agricultural improvement districts and irrigation and water conservation districts), the applicant must demonstrate that permission to pump and transport the groundwater h as been obtained from that entity. If the groundwater will be withdrawn in one county and transported to another county, the applicant must demonstrate that the county from which the groundwater will be withdrawn has consented. Authorization letters from each entity on that entity's letterhead and signed by the responsible official (such as the chairman of the board or the mayor) must be attached to the application.

Groundwater transported for drought emergency relief purposes can only be used for domestic, stockwater, or potable municipal supplies (private water providers are included in this last category if they have a Public Water System identification number). For each category, the land or provider receiving the transported groundwater must be identified. Groundwater cannot be transported from or into an AMA. The county, city, town or other political subdivision (agricultural improvement district, irrigation district, or water conservation district) in which the transported groundwater will be used must have already implemented an emergency conservation plan sufficient to prevent nonessential use of groundwater. A copy of the plan must be attached to the application. Finally, a responsible person of the organization requesting the permit must sign the application.

The Department will review the application and supporting documentation, and make a decision to approve or deny the application within 30 days from its receipt by the Department. There is no fee for this application. The Department will mail the permit to the responsible person at the organization named on the application. A permit is valid for six months, but may he terminated earlier if the Director determines that the transportation of groundwater is no longer necessary. The applicant may reapply for a six-month extension of the permit if the drought emergency persists beyond the permit period. The transportation of groundwater must stop upon the cessation of the drought emergency or the end of the permit period. Records of the amounts of water transported should be maintained. Groundwater transported away from a groundwater basin pursuant to a permit is subject to payment of damages.

Governor's Drought Task Force

Potable Water Plan

DRAFT

June 2004

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Executive Summary

The Potable Water Plan is a result of the leadership provided by Governor Napolitano through Executive Order 2003-12. The Executive Order created the Governor's Drought Task Force to develop a long-term drought plan, a statewide water conservation strategy and to address short-term water needs. As a result of this guidance, a Potable Water Plan was developed and adopted for the summer of 2003. However, in light of the conditions that continue to affect water supplies in the State of Arizona, the Governor's Drought Task Force has adopted a Potable Water Plan for the summer of 2004.

The Potable Water Plan addresses short-term water supply for political subdivisions under emergency conditions where the health and welfare of the public is at risk. The Plan introduces a methodology based on planning guidance from the National Drought Mitigation Center. There are three basic elements to the Plan: Monitoring, Assessment and Response. Each section describes specific mechanisms to provide data, determine potable water drought related risk factors, and provide response guidance to political subdivisions of the State. The Monitoring focuses on current climate conditions. The Assessment discussion identifies water providers that may face potable water delivery challenges due to drought and provides a vulnerability profile. The profile enables rural water providers (where nearly all of the potable water shortage risk is associated) to determine their own risk to drought as conditions change. The Response discussion directs at-risk water providers to the appropriate response mechanism and encourages early preparedness to mitigate drought impacts. Finally, the Plan identifies triggers to mobilize teams to accomplish objectives in each of the functional areas.

Annexes to the plan provide additional information on drought severity and impacts, guidance to water users from the Department of Health, maps of impacted areas prepared by the Arizona Department of Environmental Quality and response documents from the Arizona Division of Emergency Management.

A web link to the Plan is available on the Arizona Department of Water Resources web site. The web address is http://www.water.az.gov/gdtf/

Background:

Governor Napolitano signed Executive Order 2003-12 on March 20th 2003 creating the Governor's Drought Task Force (GDTF). The GDTF was charged with developing a drought plan for the State, a statewide conservation strategy and a plan to address short-term water supply issues for the immediate future. The Governor's Executive Order stated that precipitation throughout the State of Arizona during the past four years and for six of the last seven years has been significantly below normal. Another year of below normal precipitation has passed since the Executive Order was signed. The lack of precipitation has significantly reduced stream flows in the interior basins and has reduced surface and groundwater supplies upon which citizens and the commerce of the State are dependent. The drought conditions affect areas throughout the State but most critically in the rural areas. The Executive Order recognized that the current drought conditions directly endanger people, property, crops, livestock, and wildlife throughout the State. In addition, economic hardship caused by drought has an impact on commerce throughout Arizona. However, actions can be taken to mitigate the effects of drought even though droughts periodically reoccur across Arizona and are a natural climatic feature of the southwest. The adverse impacts can be mitigated through proper coordination of many activities such as planning and conservation measures. This focus on reducing vulnerability to future drought is a key consideration in the long-term Drought preparedness Plan.

The Governor's Executive Order designated the Arizona Department of Water Resources to lead the coordination of activities of State agencies. However, the development of the long-term drought plan will include participation of all interested parties, including Native American Tribes, political subdivisions, water providers, agriculture interests, non-governmental organizations and others. These entities have been working on the development of the long-term drought plan for the past year and will propose a plan for adoption before the end of 2004.

Potable water needs of the State received a high priority due to economic concerns and the increased health risks associated with lack of potable water for daily human needs. Therefore, the Task Force is committed to developing a Potable Water Plan that provides assistance where public health and welfare is affected by potable water shortages. The Potable Water Plan identifies water companies or providers that may have difficulty meeting their potable water demands this year. Furthermore, the Potable Water Plan also identifies locations in the State where drought-related water level declines are causing, or are likely to cause, significant losses of supply for individual domestic wells.

Introduction:

Precipitation throughout Arizona continues to be significantly below normal. During the past five years and seven of the last eight years the lack of precipitation and reduced snowpack in the higher elevations has significantly reduced stream flows in the State's interior basins. Below average snowmelt has reduced or eliminated surface water sources and forced an increasing dependency on groundwater. Water supplies upon which citizens and commerce are dependent are in jeopardy of being depleted to the point of having an impact on the health and welfare of the citizens of the State. This is especially true in rural Arizona, which depends on groundwater supplies for most of its water needs. The Potable Water Plan is focused on supporting rural areas of the State where there are few resources to mitigate the effects of drought.

Municipal water providers in the Tucson and Phoenix metropolitan areas have developed a variety of measures over the last twenty years to mitigate the effects of drought. Large water providers in these areas have already implemented drought response measures such as planning, water banking, and public education programs to encourage conservation.

The Potable Water Plan outlines a process that individuals, water providers, and political subdivisions can use to reduce the impact of potable water shortage due to drought. The importance of monitoring drought conditions to determine the risk associated with decreased water supply is explained. A risk assessment model is described and water system vulnerabilities are listed. Water providers and political subdivisions can compare water system vulnerabilities to their own areas of concern and evaluate their risk to drought. Response mechanisms are discussed to enable political subdivisions to prepare for potable water shortages. Preparedness activities could include local water curtailment planning, familiarization with current response programs and identifying, in advance, operational mechanisms to transport water.

Specific response operations to transport potable water are discussed in the State Emergency Response Incident Action Plan attached as an Annex to this plan.

IV. Climate Synopsis

The current drought in Arizona is likely to continue into next year. Arizona did receive some drought relief through rain and snow in the fall and winter, and southern Arizona benefited from early April precipitation. However, for most of the state the drought picture is only slightly improved, if at all. Moreover, the 2003 monsoon season was spatially inconsistent, and some areas, notably southeastern Arizona near the New Mexico border, received very little summer precipitation.

Several years of low winter rainfall and snow have resulted in very low reservoir levels. Parts of Arizona experienced a near normal snow-pack during the mid-winter, but record mid-March heat reduced Arizona snow accumulations to below average. A recent USDA –NRCS report, "*Arizona Basin Outlook Report April 1, 2004*", showed precipitation from the Snow Telemetry (SNOTEL) sites since October 1, 2003 in the range of 67 to 78 percent of average for key watersheds in the State. The marginal amount of snowpack that accumulated over this past winter reached a statewide maximum of only 73 percent of the 30-year average on March 1, 2004 compared to 76 percent of the 30-year average at the same time last year. Furthermore, high temperatures, low humidity, and winds rapidly reduced Arizona winter snowpack. High temperatures, low

humidity and seasonally high winds continue to dry the lowlands and forest vegetation, enhancing wildfire potential.

The wildland fire season could still be very severe, as it was in 2002 and 2003. The fire danger outlook for May 2004 predicts normal to above normal fire potential for the upcoming months. Fire danger is expected to increase to above normal levels across Arizona by the second half of May, as grasses cure and dead fuels dry. Fire danger conditions are expected to become critical across northern Arizona during the latter half of May. March and April precipitation brought fuel moistures to within normal range for this time of year; however, fuel moistures in juniper and scrub oak forests are low.

Bark beetles continue to increase the fire hazard potential. These insect pests not only cause severe economic damage due to destruction of timber, but the dead trees dramatically increase the potential for destructive wild-land fires. During the past two years, over 2.3 million acres of Arizona's forests have been killed by these very destructive forest pests in the ponderosa pine and pinyon-juniper forests. This represents a more than 43-fold increase in acreage killed by these pests since 2001. Low tree vigor caused by several years of drought and excessively dense tree stands have combined to allow beetle populations to reach outbreak levels. Vulnerability to fire in Arizona's forests is likely to continue for several years as a result of the drought and there appears to be little relief in the long-range forecast. The most severe risk areas are in communities in the wildland interface where there is a shared boundary with dead trees due to bark beetle mortality. Northern Arizona (including Coconino, Yavapai, Navajo, Gila counties) is particularly vulnerable, due to lower than average winter and spring precipitation. Communities that are vulnerable to wildland fire have an increased risk if a potable water shortage compromises fire fighting capability.

Hydrological drought conditions are likely to continue through next winter. Recent predictions are for neutral conditions to persist through July in the El Niño-sensitive region of the Pacific Ocean. After July, there is considerable uncertainty, with a slightly better than average chance of an El Niño developing. El Niño sometimes brings cool, wet conditions to Arizona during the winter months. If the neutral conditions persist, there is a better than average likelihood of a dry winter in Arizona, which would aggravate low water supply conditions that exist in some parts of the State.

Objectives:

The Potable Water Plan has several broad objectives. The first objective is to monitor climatic data and make them available to policy makers to assist decision-making. Appropriate decisions can mitigate the effects of drought on potable water usage in a number of ways. Proactive adoption of water conservation measures may allow water providers to meet demand during periods of limited drinking water availability.

Drought monitoring and analysis is important because climate data can be simplified from a complex set of data into a discussion that provides a wide audience with the information that is most useful for them. The drought discussion focuses on intensity, duration, and geographic scope. It also provides a historical reference to assist in response planning and design applications.

A second objective is to create a potable water provider assessment process to collect a list of water providers that have had historical water supply problems and determine the extent of the water delivery problems that may materialize this summer. Depending on the type of water

provider, there are a number of state agencies and at least one federal agency that provides regulatory oversight or technical assistance. The potable water assessment includes the state agencies listed below. A list of water providers (municipal and private companies) that may experience any water supply shortages was compiled based on on-going input from communities and agencies throughout the State.

The Arizona Department of Environmental Quality (ADEQ) provides regulatory oversight to protect water quality in Arizona. ADEQ provided a list of communities that have experienced water delivery problems in the past.

The Arizona Corporation Commission (ACC) provides additional regulatory oversight for privately owned providers and public service corporations. A public service corporation is any water provider entity other than a municipality, which furnishes water to the public for any purpose. These entities may include, but are not limited to, corporations, partnerships, individuals, cooperatives, homeowners associations, and others. *The ACC also monitors water providers that currently have curtailment tariff plans due to drought-related or system-related water supply disruptions*. Having a curtailment tariff plan does not automatically imply that the water provider has a vulnerability to drought related water shortage, however, it does provide a response mechanism if the provider experiences a water supply shortage of any kind.

The Arizona Division of Emergency Management (ADEM) coordinates response to emergencies within the State. The ADEM provided a list of water providers that have historically applied for disaster assistance due to potable water shortages.

The Arizona Department of Water Resources (ADWR) currently has an internal process to collect information from private well owners that have notified the agency that their well requires deepening or if a request is filed for authorization to drill a new well due to water level changes. Private wells are reviewed and approved by local health officials to determine proper setbacks for septic tanks, and the Arizona Department of Water Resources permits the actual well drilling.

The U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation also provide assistance to certain tribal water providers within Arizona, however some Indian Nations manage and regulate their own providers.

The third objective of the Plan is to develop response options that minimize the impact of potable water shortages. Although the first objective will provide water providers and policy makers with significant lead-time to allow conservation measures to be implemented, the chance of completely mitigating all water shortages through conservation measures is slight. Many parts of rural Arizona are already hauling water either out of necessity or by choice. These water users are conserving water at a remarkable level, sometimes using as little as 10 gallons per day per person *(Navajo Nation Drought Contingency Plan, 2002)*. Water conservation in some communities will have little impact on total demand. Drought-related water supply shortages in these and other communities that have implemented conservation strategies might require finding new water sources either on a temporary or permanent basis. The State Emergency Response and Recovery Plan and other federal programs may be invoked to provide water either through hauling or development of other water sources.

The Arizona Department of Emergency management, in cooperation with other state agencies, has

developed the State of Arizona Emergency Response Incident Action Plan contained in the Annex to this Plan. The Action Plan identifies a set of responses for each functional area to drought conditions and a corresponding response organization. As the severity of an event changes and the operational needs change, the response effort will ramp up to meet the needs of the incident. Adapting the response structure to fit the severity of the drought requires frequent evaluation of the drought and its impacts. Monitoring is an essential element of this evaluation. The long-range Drought preparedness Plan focuses on expanding drought response activities as conditions worsen, and contracting them as conditions improve. However, monitoring is an ongoing and essential activity, regardless of the drought stage.

V. Key Functional Areas

MONITORING

Monitor Team members may include the National Weather Service, Arizona Division of Emergency Management, Arizona Department of Water Resources, Salt River Project, the University of Arizona, the State Climatologist at Arizona State University, the U.S. Geological Survey, the Natural Resources Conservation Service, and others.

A national drought monitoring capability already exists and there are several other drought indicators that can provide significant insight to current conditions. Other climate indices in the form of long-term prediction maps are available from a variety of sources, both government and institutional. They provide additional data and discussion forums that relate to monitoring climate conditions. There are significant resources within the state that support the climate assessment and projection process. The University of Arizona has a project funded by the National Oceanic and Atmospheric Administration (NOAA) to assess the impacts of climate variability on human and natural systems. The project, Climate Assessment of the Southwest (CLIMAS), produces a monthly report *Southwest Climate Outlook* that discusses the drought and its impacts. The Arizona Division of Emergency Management is a partner in the CLIMAS project[32] and produces an Arizona specific drought monitor discussion monthly. The report is an analysis of climate and weather information that is collected from some of the available sources. Data is collected from the National Weather Service, National Drought Mitigation Center, and the Southwest Fire Center. Improvement in the report will be made through the integration of data that's currently not available on a regular basis.

The National Drought Monitor Report is available weekly and the current State report is distributed monthly. Distribution of the report will be made to a broader audience and also made available on the Governor's Drought Task Force (GDTF) web site. Climate data by its nature is slow to change; therefore, monthly reporting is adequate. However, as national products such as the National Drought Monitor and discussion are made available, the GDTF web site will be updated. The web site is located at http://www.water.az.gov/gdtf/

ASSESSMENT

Risk is defined as a function of the frequency and severity of the event, in this case drought, and vulnerability. For the purposes of the short-term Potable Water Plan the vulnerability analysis was conducted by collecting names of water providers that have historical occurrences of water shortages. The list of water providers was collated from each agency list discussed in the Objectives Section.

[32] CLIMAS website -

The first data source includes information collected by and from senior state staff with long-term experience in water supply, regulation, and quality oversight. Representatives from the Arizona Corporation Commission, Arizona Department of Water Resources, Arizona Department of Environmental Quality, Arizona Department of Health Services, and the Arizona Division of Emergency Management submitted names of water providers for analysis. Each state agency prepared a list of providers that either have historical supply issues or met another qualifying condition such as application for curtailment tariffs. Once the list was developed contact was made by the Arizona Department of Water Resources with each entity to determine the extent and nature if any of their water supply problems.

Municipally Owned Water Providers

Although there are reports of smaller wells experiencing difficulties in the Payson and Flagstaff, there are no municipally owned water providers currently experiencing water supply shortfalls although several rural water providers have reported areas of concern.

As noted earlier the large metropolitan areas of the state are less vulnerable to potable water shortages due to planning, a well developed integrated infrastructure across large basin areas and effective water conservation media campaigns.

The Arizona Department of Environmental Quality provided the map locations of rural water systems that may be affected by drought and depicts the closest potential water supply sources. The ADEQ maps are listed in an annex to this plan.

C. *Water Companies With Previously* Reported *Water Supply Problems*

Although as of the date of this report, no water company has yet reported drought-related problems in 2004, some private water companies report that should conditions continue to worsen into the summer months, they may have difficulty meeting their current water needs. Some of these systems have issues, that are not directly related to drought, however, infrastructure and storage problems can increase a systems vulnerability to drought. In order to enhance awareness to water users and visitors, water companies that have reported problems in past drought years are also being identified:

Bella Vista South – Located in an unincorporated area south of Sierra Vista, last summer this company was having difficulty meeting daily demand due to declining water levels, increased peak demand and reduced availability of water supply. A new well has been constructed to supply water to this system, however, continuation of the drought is a principal concern due to potential impacts to other wells within this system.

Pine Water Company, Pine – Located north of Payson, last summer this company reported having difficulty meeting peak demand especially during long holiday weekends. So far in 2004 this has not been an issue, however, the summer season when the visitation rate increases has not yet begun, which is the major contributor to this system's problems. Water hauling and piping water through an interconnect with Strawberry to meet peak demand as well as a more focused water conservation strategy are likely solutions.

Hunt Water Company, Strawberry - Located north of Payson, last summer this company,

like Pine Water Company, reported having difficulty meeting peak demands. As a result of increased summer visitors, they expect some intermittent outages of short duration and significant reductions in pressure. Again, a more focused water conservation strategy combined with emergency water hauling will provide sufficient water in the short term.

Beaver Valley Water – Located near the East Verde River near Payson, last summer this system experienced shortages when the East Verde River went dry. The company has installed a PVC pipe approximately ½ mile upstream to a spring that feeds the East Verde, however, if the drought continues there is some concern that the spring could be impacted in addition to the River going dry again this summer.

Black Canyon Water Improvement District (Black Canyon City) – Located north of Phoenix, this system had declines in groundwater in the summer of 2002. The water company reports the need for a good monsoon season to keep them out of the same situation.

Coldwater Canyon (Black Canyon City) - Located north of Phoenix, this system had declines in groundwater in the summer of 2001. The water company reports the need for a good monsoon season to keep them out of the same situation.

Mt. Tipton (Dolan Springs) – Located in Mojave County, this system provides a significant portion of their supplies to water haulers in the area.

Mayer – Located west of Prescott, this water system has experienced problems in meeting peak demands due to issues with aging infrastructure.

Navajo Depot – Located near Flagstaff, this water system hauled water in 2002 due to drought conditions. They are currently reporting no problems.

Park Water Company – Located south of Florence, last summer this water company was having difficulty meeting daily demands due to inadequate storage and supply. The company hauled water to meet demand during June, July, August, and September of 2003. The activation of a refurbished wellsite should resolve the inadequate storage problem and provide additional supply.

United Utilities/East Verde – Located near Payson, this system has experienced problems meeting peak demands, however, they have an active water hauling program.

Walden Meadows – Locate northwest of Wickenburg, this water system continues to have operational and infrastructure problems unrelated to drought – with only one well, meeting peak demands can be problematic. With continued drought, this system could see additional impacts.

D.

E. ***Water Providers With* Potential *Water Supply Problems This Summer***

The following water providers are located in areas that have experienced past problems due to drought and although they are not currently reporting any problems and may not have experienced direct problems due to drought, they are being identified to increase public awareness that in certain areas of the State, water use habits can have significant impacts:

PROVIDER	
Pine Creek Water (Pine)	Currently Reporting No Problems
Strawberry Hollow (Pine)	Currently Reporting No Problems
Strawberry Water	Currently Reporting No problems
Peeples Valley	Historic Declines in a few Wells – Infrastructure
Pine Canyon Methodist (Chiricahua)	Currently Reporting No Problems
Belmont (Flagstaff)	Currently Reporting No Problems
Parks (Flagstaff)	Currently Reporting No Problems
Williams	Watching Surface Water Supplies (Constructing New Well)
Payson	Currently Reporting No Problems – Stage 3 Conservation Level
Flagstaff	Currently Reporting No Problems

The second data source is the analysis of responses to a rural water provider survey recently conducted by the Arizona Department of Water Resources. Three separate surveys were distributed throughout the State. One survey was sent to 500 water providers, the second survey instrument was sent to cities and towns, and the third was sent to Counties and Tribes. To date 19 surveys were returned to the Arizona Department of Water Resources from the political subdivisions and 121 water providers have responded. Three questions in the surveys were relevant to the potable water vulnerability analysis.

The combined analysis of the questions represents a comprehensive list of underlying causes for water shortages and therefore is representative of water shortage vulnerabilities. An additional question asked if the water provider hauled water last year (2002) in response to water shortage.

The vulnerability criteria were developed from the analysis of the surveys of water providers and jurisdictions and includes the following:

Peak demand exceeds supply
Inadequate storage to meet peak demand
Inadequate pumping capacity to meet peak demand
Inadequate storage to meet long-term demand
Undersized distribution system
Inadequate water production
Infrastructure related problems/system failure
Insufficient water supply (source)
Inability to meet water quality standards

The following is an analysis of the available data as of June 17th, 2003:

Water Providers

Just over a fifth of the respondents (26) reported that the drought has had an impact on their water supply. The balance of the responses (95) indicated that they do expect to have challenges consistent with one or more of the areas of vulnerability. The most common reported vulnerability was the declining ground water levels (24), and increased peak demand (17) among water providers. Currently there are at least two water providers that reported hauling water in response to drought, although four reported that hauling water is a normal part of their operation.

Political Subdivisions

The political subdivisions (19 reported) were asked if the drought had an effect on their water supply. Seven political jurisdictions reported that drought did affect their operation. The most common reason cited was reduced supply (5) and lower groundwater tables (5) followed by increased demand for potable water (4).

Individual Wells: Reported areas of concern

Small capacity domestic wells are often vulnerable to the effects of drought. In many areas of the state there are large numbers of densely located domestic wells that produce marginal volumes of water from cracks or fissures in hard rock formations. When droughts occur, the natural recharge to aquifers diminishes and water levels decline. This situation can be particularly problematic for shallow wells because water production can drop off to unacceptable levels, or wells can go completely dry. The Arizona Department of Water Resources is currently monitoring public contacts concerning water well and water supply problems that may be related to the Southwest's ongoing multi-year drought. Between April and May the Department has received several reports from well owners and/or well drillers of domestic wells losing production capacity or going dry in several parts of the state.

There is some difficulty in clearly distinguishing between domestic well problems that are solely caused by the drought and problems that may be related to the impacts of other nearby wells. Wells that were reported to have gone dry in the Prescott area ranged from about 240 to 300 feet in depth and were located in hard rock areas with comparatively high densities of nearby wells. Other wells that were reported to have gone dry are located in the central part of the state near Apache Junction and Florence. Depths for these wells range from 220 to 310 feet. The impact of drought and the competition of nearby wells are potential causes of these well problems. A shallow 40-foot well was reported to have gone dry along the Santa Cruz River near Nogales. The failure of this well is undoubtedly attributable to the lack of stream flow and recharge that often occurs during the summer months along that reach of the Santa Cruz River. Applications have been filed to replace or deepen many of the wells mentioned.

The ADWR anticipates there may be many more reports of drought-related domestic well problems as the summer season progresses. These reports will be monitored and analyzed along with available water level data to help the Department identify other vulnerable areas of the state where drought-related water level declines are likely to cause significant losses of supply for individual domestic wells. This analysis will help form the basis for both short-term relief efforts and long-term plans and strategies to deal with this important concern.

The potable water providers identified as being previously reported or have potential vulnerabilities should be routinely assessed throughout the summer to anticipate any response actions that may be necessary. The Arizona Department of Water Resources, Arizona Corporation Commission, Arizona Department of Environmental Quality, Arizona Department of Health Services and the Arizona Division of Emergency Management will meet on a regular basis to share assessment data and evaluate any other water providers that have the potential to experience water shortages. The Arizona Department of Water Resources staff has established routine contact with the water providers that are currently experiencing water delivery challenges to provide a constant assessment profile.

RESPONSE

Response to a potable water emergency should include a concentrated effort to reduce the demand for potable water through conservation measures. The Arizona Corporation Commission has a curtailment plan format that has been used for a number of private water companies that describes specific actions that might mitigate the effects of the shortage that can be taken in advance of an emergency. However, conservation measures may not be successful if water use is already limited to essential uses or the water supply is a fraction of the volume needed. In some cases, drought related potable water shortages might only be alleviated through the augmentation of the water supply, generally through transfer or hauling water.

Prior to hauling water, regulatory considerations should be considered. The Arizona Corporation Commission requires a notification process for private water companies that are under their jurisdiction. In addition, the state Groundwater Code prohibits most transfers of groundwater from basin to basin. However, under emergency conditions requests to transfer water will be evaluated by the Director of ADWR on a case-by-case basis.

The State's surface water laws protect the use of surface water. A surface water claim or right authorizing the use of the water at the location is requirement of either State or Federal law.

Where conditions result in a lack of potable water either due to infrastructure failure or drought related water supply limitations, response actions can be taken to assist political subdivisions. Where the health or welfare or the citizens of the State is a concern, the Governor has the authority to declare an emergency that authorizes the State Emergency Response and Recovery Plan to be invoked. Under the State plan, political subdivisions are eligible for reimbursement of 75% of their costs to haul water. Jurisdictions that seek to use this authority should contact their local emergency manager or contact the Arizona Division of Emergency Management for guidance. An Annex to this plan includes a checklist for local jurisdictions that may require assistance.

Political subdivisions that anticipate needing assistance based on risk assessments against the vulnerability profile should contact their county emergency response program coordinator to begin to identify operational needs.

The Arizona Division of Emergency Management will notify the State assessment team to enable each State agency with specific responsibilities in the State Emergency Response and Recovery Plan and the Potable Water Incident Annex to complete assignments. Early assessment and frequent communication with drought affected political subdivisions is strongly encouraged.

Annex: Governor's Executive Order
Annex: Current Arizona Drought Discussion
Annex: State Emergency Response Incident Action Plan
Annex: Arizona Department of Health Services: Drought Information Sheets

APPENDIX III
DROUGHT TASK FORCE MEMBERSHIP

Donald Butler	AZ Dept of Agriculture
Anne Alvarado	AZ Dept of Commerce
Steve Olea	AZ Corporation Commission
Chuck McHugh	AZ Dept of Emergency Management
Karen Smith	AZ Dept of Environmental Quality
Richard Rico	AZ Game & Fish Dept
Alan Stephens	Governor's Office
Kristina Schaller	AZ Dept of Health Services
Representative Tom O'Halleran	AZ House of Representatives
Speaker Jake Flake	AZ House of Representatives
Roy Tanney	AZ Dept of Real Estate
Senator Linda Binder	AZ Senate
Kirk Rowdabaugh	AZ State Land Dept.
Jim Dorre	AZ Dept of Transportation
Herb Guenther	AZ Dept of Water Resources

APPENDIX IV
DEFINITIONS/ACRONYMS

Acre-feet (AF): The amount of water it takes to cover one acre of land to a depth of one foot, approximately 325,851 gallons.

Active Management Area (AMA): A geographical area designated by the Arizona Department of Water Resources (ADWR) as requiring active management of groundwater. Four initial active management areas currently exist in central and southern Arizona within the regions of Phoenix, Pinal, Prescott and Tucson. A fifth active management area was established in Santa Cruz requiring the active management of any water, other than stored water, withdrawn from a well. Subsequent active management areas may be designated through local initiative or by the Director of the Department.

Adjudication: A judicial determination or establishment of the extent and priority of all the surface water rights for any river system and source.

Agricultural Use: Agricultural use includes water supplied for irrigation of crops grown for human or animal consumption.

Alternative Water Supply: A water source, other than groundwater, pumped within an AMA.

Animal Industry Use: The production, growing and feeding of livestock, range livestock or poultry.

Annual Groundwater Allotment: The total amount of groundwater a Grandfathered Right (GFR) holder is authorized to withdraw annually.

Aquifer: A geologic formation that contains sufficient saturated materials to be capable of storing water and transmitting water in usable quantities to a well.

Area of Impact: The area where stored water has migrated or is located, as projected on the land surface.

Artificial Recharge: Water recharged to the aquifer through recharge projects, which may be recovered in the future based on accrued recharge credits.

Assigned Irrigation Efficiency: The maximum economically feasible levels of conservation within areas of similar farming conditions which each IGFR holder is expected to achieve.

Assured Water Supply (AWS): A water supply that meets all of the following criteria as defined in Rules:

1. Physical, legal and continuous availability for 100 years;
2. Meets water quality standards;
3. Demonstrated 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.

Atlantic Multidecadal Oscillation (AMO): Annual ocean temperature anomalies averaged across the North Atlantic

Augmentation: To supplement the water supply of an AMA, which may include the importation of

water into the AMA and the storage of water.

Baseflow: The part of a stream discharge that is not attributable to direct runoff from precipitation or melting snow. It is sustained by groundwater discharge and may be considered as the normal day-to-day flow during most of the year.

Body of Water: A constructed body of water or interconnected bodies of water, including a lake, pond, lagoon, or swimming pool, that has a surface area greater than 12,320 square feet when full and that is filled or refilled primarily for landscape, scenic or recreational purposes, or regulatory storage.

Beneficial Use: Includes, but is not limited to, use for domestic, municipal, recreation, wildlife (including fish), agricultural, mining, stockwatering and power purposes.

Central Arizona Project (CAP): The reclamation project and works authorized to bring about 1.5 million acre-feet of Colorado River water per year to Pima, Pinal and Maricopa counties.

Central Arizona Water Conservation District (CAWCD): The multi-county water conservation district established as a special taxing district for the purpose of contracting with the U.S. for the delivery of CAP water and the repayment of associated CAP costs.

Certificate of Assured Water Supply: A permit issued by the director for a development, other than a master-planned community, after the director determines that an assured water supply exists for the development pursuant to A.R.S. §45-576 and Article 7 of the Assured Water Supply Rules.

Certificate of Exemption: A certificate issued by the State Land Dept. or the AZ Corporation Commission, prior to the 1980 Groundwater Management Act. The amount of groundwater use described by an application for a certificate of exemption is recognized as a legal use for the purpose of determining Type 2 non-irrigation grandfathered rights, subject to the finding of mistakes upon appeal.

Colorado River Water: Water from the main stem of the Colorado River.

Committed Demand: Water demand associated with platted, undeveloped lots that will be served in the future. This demand must be included in calculations used to satisfy the AWS rules.

Conservation: The preservation and planned management of water resources to ensure the future availability of water resources.

Conservation District: A multi-county water conservation district established as a special taxing district. Currently, this includes only the Central Arizona Water Conservation District (CAWCD).

Conservation Potential: The amount of reduction in water use which, based on existing water use, can be achieved from implementing reasonable conservation measures or programs.

Consumptive Use (CU): The total amount of water taken up by vegetation for transpiration or building of plant tissue, plus the unavoidable evaporation of soil moisture, snow, and intercepted precipitation associated with vegetal growth.

Convey: To transfer the ownership of a grandfathered right from one person to another.

Deficit Irrigation: The intentional practice of reducing the number of irrigation applications to lower crop production costs while achieving acceptable yields.

Designation of Assured Water Supply: A decision and order issued by the director designating a municipal provider as having an assured water supply pursuant to statute and the Assured Water Supply Rules.

Direct Use Effluent: Effluent that is transported directly from a facility regulated pursuant to water quality control statutes, to an end user. Effluent that is delivered directly from a wastewater treatment facility is included in this definition, while effluent that is recharged is excluded.

Diversion: The taking of water from a stream or other body of water into a canal, pipe, or other conduit.

Domestic Use: Uses related to the supply, service, and activities of households and private residences and includes the application of water to less than two acres of land to produce plants or part of plants for sale or human consumption, or for use as feed for livestock, range livestock or poultry, as such terms are defined in 3-1201.

Drought: A sustained natural reduction in precipitation that results in negative impacts to the environment and human activities.

El Niño-Southern Oscillation (ENSO): A multi-season to multi-year variation in equatorial Pacific Ocean temperatures and associated atmospheric circulation.

Effluent: Water that has been collected in a sanitary sewer for subsequent treatment in a facility that is regulated as a sewage system, disposal plant or wastewater treatment facility. Such water remains effluent until it acquires the characteristics of groundwater or surface water.

Entitlement: The maximum amount of water a user can put to beneficial use. Water entitlements are normally associated with water rights and water right decrees. An entitlement can also be specified in a contract, agreement, or settlement.

Evapotranspiration (Et): Loss of water from the land through transpiration of plants and evaporation from the soil and surface water bodies.

Excess Central Arizona Project (CAP) Water: CAP water that in any year would otherwise not be delivered to CAP subcontractors or their designees.

Exempt Well: A well with a maximum pumping capacity of not more than 35 gallons per minute, which is used to withdraw groundwater for non-irrigation purposes.

Extinguish: To cause a grandfathered groundwater right to cease to exist through a process established by the director pursuant to rule. Grandfathered rights are extinguished to meet AWS consistency with management goal requirements for obtaining a certificate or designation of assured water supply within an active management area.

Farm: An area of irrigated land that is under the same ownership, which is served by a water distribution system common to the irrigated land and to which can be applied common conservation, water measurement and water accounting procedures.

Geology: The structural and mineral constitution of the earth (dictionary definition).

Geomorphology: The characteristics, configuration and evolution of rocks and land forms (dictionary definition).

Grandfathered Right(GFR): A right to withdraw and use groundwater within an AMA based on the fact of lawful withdrawals and use of groundwater prior to the AMA's designation. These rights include Irrigation Grandfathered Rights, Type 1 Non-Irrigation Grandfathered Rights, and Type 2 Non-Irrigation Grandfathered Rights.

Groundwater: 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 underground streams with ascertainable beds and banks.

Groundwater Basin: An area which may be designated so as to enclose a relatively hydrologically distinct body or related bodies of groundwater, which shall be described horizontally by surface description.

Groundwater Replenishment District (GRD): A district established as a special taxing district to develop, store, augment, conserve, replenish or otherwise increase water supplies for the benefit of the district members, consistent with achieving safe-yield.

Groundwater Savings Facility (GSF): A facility within an AMA or INA at which groundwater withdrawals are eliminated or reduced by recipients who use in lieu water on a gallon-for-gallon substitute basis for groundwater that otherwise would have been pumped from within that AMA or INA.

Groundwater Withdrawal Permit: Permits issued by ADWR for withdrawing groundwater under the following categories: dewatering (permanent or temporary), mineral extraction and metallurgical processing, general industrial use (GIU), poor quality groundwater, electrical energy generation (temporary), drainage, and hydrological testing.

Impacts: Economic, social, and environmental effects that occur, either directly or indirectly, as a result of drought, which can vary across the state based on climatic and social activities.

In Lieu Water: Water that is delivered to a groundwater savings facility and that is used in an AMA or INA by the recipient on a gallon- for-gallon substitute basis for groundwater that otherwise would have been pumped from within an AMA or INA.

Incidental Recharge: The amount of water that percolates down to the water table after it is used, excluding water that is added to an aquifer pursuant the underground storage, savings and replenishment program.

Indicators: Variables to describe drought conditions (examples - precipitation, stream flow, groundwater, reservoir levels, soil moisture, etc.).

Industrial Use: Within an AMA, non-irrigation use of water not supplied by a city, town or private water company, including animal industry use and expanded animal industrial use.

Influent: Raw, untreated wastewater flowing into a wastewater treatment plant.

Interstate Stream: Any stream constituting or flowing along the exterior boundaries of this state, and any tributary originating in another state or foreign country and flowing into or through this state.

Irrigation Acre: An acre of land to which an irrigation grandfathered right is appurtenant.

Irrigation District (ID): A political subdivision established as a special taxing district for either

agricultural improvement or irrigation and conservation purposes.

Irrigation Efficiency: The maximum economically feasible levels of conservation that each IGFR holder is expected to achieve within areas of similar farming conditions (ASFC), calculated as a percentage. 100 percent efficiency would be achieved by using only the amount of water physiologically needed by the plant, while 75% efficiency would be 1.25 times that amount. For example, a farm assigned a 75% irrigation efficiency for a crop requiring 100 acre-feet of water per acre annually, could legally use 125 acre-feet of groundwater (100 acre-feet x 1.25) annually.

Irrigation Grandfathered Rights (IGFR): A right to irrigate land in an active management area that was legally irrigated any time between 1975 and 1979, based on crops historically grown for which a certificate has been obtained, with a few exceptions for substitution or transfer of acres under specified circumstances. The process for determining acres entitled to and for calculating a groundwater allocation is specified in A.R.S. § 45-465.

Irrigation Non-Expansion Area (INA): A geographical area that has been designated as having insufficient groundwater to provide a reasonably safe supply for the irrigation of the cultivated lands at the current rate of withdrawal. Within INAs, new agricultural use of land occurring on land that was not irrigated in the five years preceding the designation of the INA is prohibited with a few exceptions for substitution or transfer of acres under specified circumstances.

Irrigation Use: Within an AMA, use of groundwater on two or more acres of land to produce plants or parts of plants for sale or human consumption, or for use as feed for livestock, range livestock or poultry. In the Santa Cruz active management area, this definition is expanded to include all water, other than stored water, withdrawn from a well. Outside of the AMAs, use of all water to irrigate crops for sale or human consumption, or for use as feed for livestock, range livestock or poultry, or wildlife.

Irrigation Water Duty: The amount of water, measured in acre-feet per acre that is reasonable to apply to irrigated farmland, based on crops historically grown from 1975 to 1979.

Long-term Drought: A measure of the severity of drought when sustained precipitation deficits over time periods of one to several years affect surface and subsurface water supplies.

Long-Term Storage Account: An account established to credit water stored pursuant to a water storage permit at a water storage facility if the water cannot reasonably be used directly and, if the storage facility were within an AMA, the water would not be naturally recharged to the AMA.

Large Untreated Provider: Municipal water providers serving at least 100 acre-feet of untreated water to at least 500 persons annually, as of January 1, 1990.

Lost and Unaccounted for Water: The total amount of water from any source, except direct use effluent, that is withdrawn, diverted or received in a year by a municipal provider minus the total amount of authorized deliveries made by the municipal provider that year.

Lost Water: Water from any source, including effluent, which enters a distribution system and is lost from the system during transportation or distribution due to seepage, evaporation, leaks, breaks, phreatophyte use, or other causes.

Managed Underground Storage Facility: A facility designed and managed to utilize the natural channel of a stream to store water underground through artificial and controlled releases of water other than surface water naturally present in the stream. Surface water flowing in its natural channel is not a managed underground storage facility.

Maximum Contaminant Level: A primary maximum contaminant level (MCL) represents a drinking water standard set by the Safe Drinking Water Act and enforced by the EPA. An MCL reflects a national primary drinking water regulation in the form of an enforceable numeric drinking water standard representing the maximum permissible level of a constituent in a public water system. A secondary maximum contaminant level (SMCL) represents a non-enforceable numeric standard for the aesthetic quality of drinking water, such as taste, odor, or color. Waters with contaminants above a SMCL are not typically expected to cause health problems.

Mined Groundwater: The amount of groundwater withdrawn or received by regulated water users within an AMA during a calendar year for beneficial use, minus incidental recharge.

Mitigation: Pre-drought actions or programs that reduce risk and impacts and enhance recovery.

Municipal Provider: A city, town, private water company or irrigation district that supplies water for municipal use.

Municipal Use: All non-irrigation uses of water supplied by a city, town, private water company or irrigation district.

Net Natural Recharge: The volume of water that naturally recharges the groundwater supply minus natural depletions to the groundwater supply.

Non-Exempt Well: A well with a maximum pumping capacity of more than 35 gallons per minute which is used to withdraw groundwater for non-irrigation purposes only.

Non-Irrigation Grandfathered Right: Refers to grandfathered rights that are associated with irrigated land retired after January 1, 1965 in anticipation of a non-irrigation use, and to grandfathered rights that are not associated with retired irrigated land.

Non-Residential Customer: A person who is supplied water by a municipal provider for a non-irrigation use other than a residential use.

Overdraft: A term signifying that more groundwater is being pumped than the amount of water naturally or incidentally recharged to the aquifer.

Overseeding: Planting a cool season grass species that grows over dormant warm season grasses during the fall/winter period.

Pacific Decadal Oscillation: A shift in the temperature pattern of the northern Pacific, which occurs on a 20 – 30 year cycle.

Potential Claimant: All persons claiming water rights or on whose behalf claims to water rights are asserted.

Present Perfected Rights: These are water rights for use of water along the lower Colorado, which were acquired through state water law prior to the enactment of the Boulder Canyon Project Act in 1929.

Prior Decree: Any judgment or decree entered by a court of competent jurisdiction that applies to the water right claim or use that is subject to adjudication.

Prior Filing: A notice of appropriation recorded with the County Recorder or the Recorder's

predecessor, a filed application to appropriate, a filed statement of claim or a filed claim of water right, any or all of which reasonably relate to the water right claim or use that is subject to adjudication.

Private Water Company (PWC): Any entity that distributes or sells groundwater, except a political subdivision or an entity that is established as a special taxing district. A special taxing district is not regulated as a public service corporation by the ACC under a CCN. A city or town is not a private water company. This definition does not apply to the Santa Cruz AMA. In the Santa Cruz AMA, this definition is expanded to include water, other than stored water, withdrawn from a well.

Public Utility: Any person, corporation, district, electric cooperative, public agency or political subdivision of the state that provides electrical service to the public by means of electric facilities or provides water for municipal, industrial, irrigation, recreation and fish and wildlife purposes to the public.

Public Waters: 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.

Reasonable Conservation Measures (RCM): Policies, practices, rules, regulations, ordinances or the use of devices, equipment, or facilities that are either an established and generally accepted practice of water conservation or a practice supported by sufficient data to indicate significant conservation or conservation-related benefits can be achieved in the NPCCP.

Residential Customer: A person who is supplied water by a municipal provider for a residential use.

Residential Use: A non-irrigation use of water related to the activities of a singe family or multifamily housing unit or units, including exterior water use.

Response: An action implemented as a result of drought that is short-term and is aimed at reducing impacts and enhancing recovery.

Riparian Area: A geographical area that is characterized by deep-rooted plant species that occurs within or adjacent to a natural perennial or intermittent stream channel, lake, pond or marsh bed maintained primarily by natural water sources. Riparian area does not include areas in or adjacent to ephemeral stream channels, artificially created stockponds, man-made storage reservoirs constructed primarily for conservation or regulatory storage, municipal and industrial ponds or man-made water transportation, distribution, off-stream storage and collection systems.

River System and Source: All water appropriable as public waters and all water subject to claims based upon federal law.

Sand and Gravel Facility: A facility that produces sand and gravel and that uses more than 100 acre-feet of water from any source annually, regardless of the nature of the water use.

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 the AMA.

Sanitary Sewer: Any pipe or other enclosed conduit that carries, among other substances, any water-carried wastes from residences, commercial buildings, industrial plants or institutions.

Service Area: For a city or town, the area of land actually being served water, for a non-irrigation use, plus additions which contain an operating distribution system owned by the city or town and the service area of a city, town or private water company that obtains its water from the city or town prior to an AMA's designation. For a private water company, the area of land of the private water company actually being served water, for a non-irrigation use, by the private water company plus additions which contain an operating distribution system owned by the private water company primarily for a non-irrigation use.

Service Area Right: The right of a city, town, private water company and irrigation district to withdraw and deliver groundwater to its customers, subject to the AMA's conservation requirements and the AWS rules.

Short-term Drought: Measures the severity of drought by the departure of precipitation or another drought indicator from average conditions on a time-scale from one to several months.

Spillwater: Water, other than Colorado River water, released for beneficial use from storage, diversion or distribution facilities to avoid spilling that would otherwise occur due to uncontrolled surface water inflows that exceed facility capacity.

Stock Pond: An on-channel or off-channel impoundment of any size that stores water that is appropriable as pubic waters and that is for the sole purpose of watering livestock and wildlife, excluding ponds used primarily for fishing or the culturing of fish. The pond must have a capacity of not more than 15 acre feet.

Storage Capacity: The maximum volume of water that can be impounded by a reservoir when there is no discharge of water.

Storage Facility: A groundwater savings facility or an underground storage facility.

Stored Water: Water that is stored underground for the purpose of recovery pursuant to a underground water storage, savings and replenishment permit.

Subbasin: An area which may be designated so as to enclose a relatively hydrologically distinct body of groundwater within a groundwater basin, as described horizontally by surface description.

Subdivision: Improved or unimproved land(s) divided or proposed to be divided for the purpose of sale or lease, whether immediate or future, into six or more lots, parcels or fractional interests. Subdivisions by definition do not include leasehold offerings of one year or less or to the division or proposed division of land(s) into lots or parcels that are each 36 acres or more in area.

Subflow: Those waters which first slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream.

Subsidence: The settling or lowering of the surface of land that results from the withdrawal of groundwater.

Surface Water: The waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwater, wastewater or surplus water, and of lakes, ponds and springs on the surface. For the purposes of administering this title, surface water is deemed to include Central Arizona Project water.

Tailings: The slurry of water and fine-grained waste rock material remaining after minerals have been removed in the mill concentrator and excess water has been recovered and returned to the mill concentrator.

Triggers: Specific values of each indicator that initiate and terminate each drought status level, and subsequent suggested management responses.

Turf-Related Facility: Any facility, including cemeteries, golf courses, parks, schools, or common areas within housing developments, with a water-intensive landscape of at least 10 acres.

Type 1 Non-Irrigation Grandfathered Right: A non-irrigation grandfathered right associated with retired irrigated land. A Type 1 non-irrigation right generally allows a rightholder to either withdraw or receive no more than three acre-feet of groundwater per acre per year for a non-irrigation use on the retired land. Type 1 non-irrigation rights may not be transferred to another location, although groundwater pumped from appurtenant areas may be transported to a new location for non-irrigation uses subject to certain restrictions.

Type 2 Non-Irrigation Grandfathered Right: A non-irrigation ground right issued based on groundwater non-irrigation uses from 1975 to 1979. Generally, Type 2 non-irrigation grandfathered rights equal the maximum amount of groundwater withdrawn and used for non-irrigation purposes in any one of the five years preceding June 12, 1980. Type 2 non-irrigation grandfathered rights may be transferred to new locations within the same active management area through either a sale or lease.

Underground Storage Facility (USF): A constructed underground storage facility or a managed underground storage facility.

Untreated Water: Water that is not treated to improve its quality, and that is supplied by a municipal provider or irrigation district through a distribution system other than a potable water distribution system.

Vulnerability: Refers to the level of risk of an area, water supply, or water user for suffering negative consequences as a result of the temporary or permanent reduction in a water supply as a direct result of drought.

Wastewater: Water that is discharged after an industrial or municipal use, excluding effluent.

Water Banking Services: Services provided by the AWBA to persons and Indian communities in this state to facilitate the storage of water and stored water lending arrangements. Water banking services include only arrangements by which water will be made available for use in this state; obtaining water storage permits; accruing, exchanging and assigning long-term storage credits; and lending and obtaining repayment of long-term storage credits. Water banking services do not include interstate water banking undertaken by the Arizona Water Banking Authority (AWBA).

Water Banking Services Agreement: An agreement entered into between the AWBA and a person or Indian community in this state under which the AWBA will provide water banking services to that person or Indian community.

Water District: A special taxing district, within an AMA, that has adopted an ordinance or resolution to undertake water district groundwater replenishment obligations.

Water Duty Acres: The acres of land of a farm which are used in calculating the maximum amount of groundwater which may be used pursuant to an IGFR.

Water Exchange: A trade between one or more persons, or between one or more persons and one or more Indian communities, of any water for any other water, if each party has a right or claim to use the water it gives in exchange. This definition applies whether or not water is exchanged in equal amounts or other consideration is included in the exchange.

Water Exchange Contract: A valid written or oral contract for a water exchange.

Water Storage Permit: A permit to store water at a storage facility.

Water Use Efficiency: The physiological needs of the plants being watered divided by the amount of water actually applied, expressed as a percentage.
Ex: 100 acre-feet needed/125 acre-feet used = 75% efficiency

Water-Intensive Landscaped Areas: An area of land that is watered with a permanent water application system and is primarily planted with plants that are not defined by ADWR as low water use/drought tolerant plants, plus the total surface water area of all bodies of water within the facility (excluding bodies of water used for swimming purposes).

Water Use Contract: This is a contract with the United States Department of Interior for the delivery and use of Colorado River water. The contract normally specifies the total amount of water use ("entitlement"), the location of the diversion, the location of the use, if for irrigation, the total amount of acres to be irrigated, and the period of use. Water from the Colorado River cannot legally be used without a contract.

Well: A man-made opening in the earth through which water may be withdrawn or obtained from beneath the surface of the earth, excluding oil, gas, helium, and geothermal wells.

Zoonotic: Relating to or constituting any infectious disease that can be transmitted from animals, both wild and domestic, to humans. The word is derived from Greek words *zoon* (animal) and *nosos* (disease).

Appendix V

COLORADO RIVER – DESCRIPTION OF ARIZONA PRIORITIES FOR COLORADO RIVER WATER AND CONTRACTORS BY PRIORITY ORDER

Description of Arizona Priorities for Colorado River Water

Priority	Description
1st	Satisfaction of Present Perfected Rights as defined and provided for in *Arizona v. California* Decree.
2nd	Satisfaction of Federal Reservations and Perfected Rights established or effective prior to September 30, 1968 (2nd and 3rd priority are co-equal)
3rd	Satisfaction of entitlements pursuant to contracts between the United States and water users in the State of Arizona executed on or before September 30, 1968 (2nd and 3rd priority are co-equal)
4th	Satisfaction of Entitlements pursuant to: (1) contracts, Secretarial reservations, and other arrangements between the U.S. and water users in the State of Arizona entered into or established subsequent to September 30, 1968 for use on Federal, State, or privately owned lands in the State of Arizona (for a total quantity not to exceed 164,652 acre-feet of diversions annually); and (2) Contract Number 14-06-W-245 dated December 15, 1972, as amended between the U.S. and the Central Arizona Water Conservation District for Delivery of Mainstream Water for Central Arizona Project, including use of Mainstream Water on Indian Lands. Entitlements having fourth priority as defined in (1) and (2) herein are coequal. Reductions in Entitlements having fourth priority shall be borne by each entitlement holder in the same proportion as its entitlement, or as required by law or regulation. If, however, a reduction-sharing agreement is entered into between two or more such authorized users, then the reduction shall be shared among the parties as provided in the agreement, subject to approval by the Contracting Officer after consultation with the Arizona Department of Water Resources.
5th	Satisfaction of Entitlements to any unused Arizona entitlement. Any entity with a contract for fifth priority water shall utilize its fifth priority entitlement only after the Contracting Officer has determined that Mainstream Water is available under applicable law or regulation, and the Contracting Officer provides written notification that such Mainstream Water is available in a specific year, subject to the provisions of the contract. Reduction or elimination of the fifth priority water use shall be determined by the Contracting Officer after consultation with the Arizona Department of Water resources, or on the basis of the contract dates, or as required by law or regulation.
6th	Satisfaction of Entitlements to Surplus Apportionment Water. Any contractor for sixth priority water shall use its sixth priority Entitlement only after the Contracting Officer has determined that Mainstream Water is available under applicable law or regulation, and the Contracting Officer provides written notification that such Mainstream Water is available in a specific year, subject to the scheduling and reduction provisions of the contract. Reduction or elimination of the sixth priority water use shall be determined by the Contracting Officer or on the basis of the contract dates, or as required by law or regulation.

Priority Listing of Arizona Colorado River Contractors

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
Priority 1 – Present Perfected Rights				
Priority 1 – Federal				
Cocopah Indian Reservation	Present Perfected Right No. 1 and Present Perfected Right No. 8	1/1/1915 9/27/1917	7,681 and 1,140	
Colorado River Indian Tribes	Present Perfected Right No. 2	3/31/1865 11/22/1973 11/16/1874	662,402	
Fort Mojave Indian Reservation	Present Perfected Right No. 3	9/18/1890 1/1/1911		
		Total: Priority 1 Federal	774,758	
Priority 1 – Water Projects				
Yuma County Water Users' Association (Valley Division, Yuma Project)	Present Perfected Right No. 4	1/1/1901	254,200	
Unit "B" Irrigation and Drainage District (Unit "B", Yuma Auxiliary Project)	Present Perfected Right No. 5	7/8/1905	6,800	
North Gila Valley Irrigation District (North Gila Valley Unit, Yuma Mesa Division, Gila Project)	Present Perfected Right No. 6	7/8/1905	24,500	
		Total: Priority 1 Water Projects	285,500	
Priority 1 – Other				
Powers	Present Perfected Right No. 7	1/1/1915	50,000	
Brooke Water LLC	Present Perfected Right No. 9	1/1/1910	360	
Hulet	Present Perfected Right No. 10	1/1/1902	1,080	
Hopel (formerly Hurschler)	Present Perfected Right No. 11	1/1/1902	1,050	
Miller	Present Perfected Right No. 12	1/1/1902	240	
McKellips/Granite Reef Farms	Present Perfected Right No. 13	1/1/1902	810	
Sherill and Lafollette	Present Perfected Right No. 14	1/1/1902	1,080	
Molina	Present Perfected Right No. 15	1/1/1928	318	
Gila Monster Farms	Present Perfected Right No. 16	1/1/1925	780	
Zozoya	Present Perfected Right No. 17	1/1/1912	720	
Swan	Present Perfected Right No. 18	1/1/1902	960	
Phillips, Milton and Jean	Present Perfected Right No. 19	1/1/1900	42	
Town of Parker	Present Perfected Right No. 20	1/1/1905	630	400
City of Yuma	Present Perfected Right No. 21	1/1/1893	2,333	1,478
		Total: Priority 1 Others	11,363	1,878

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
PRIORITY 2 / 3				
Priority 2 / 3 – Federal				
Ak-Chin Indian Community	AK-CHIN121180A	1/1/1956	50,000	
Department of the Navy – Marine Corps Air Station – Yuma	14-06-300-937	1/1/1959	3,000	
Lake Mead National Recreation Area – National Park Service	Supreme Court Decision		Unquantified	
Salt River Pima Maricopa Indian Community	SRPMIC021288N	3/4/1952	22,000	
Lower Colorado River Dams Project – USBR: Davis Dam	Secretarial Reservation dated November 29,2000	4/26/1941	100	
		Total: Priority 2 /3 Federal	75,100	
Priority 2 / 3 – Water Projects				
Unit "B" Irrigation and Drainage District (Unit "B", Yuma Auxiliary Project)	Water Rights Certificates 14-06-300-44	12/22/1952	Unquantified	
North Gila Valley Irrigation and Drainage District (North Gila Valley Unit), Yuma Irrigation District (South Gila Valley Unit), Yuma Mesa Irrigation and Drainage District (Mesa Unit, Yuma Mesa Division, Gila Project)	14-06-W-54 14-06-W-102 14-06-300-1270	1/1/1956		250,000
Wellton-Mohawk Irrigation and Drainage District (Wellton-Mohawk Division, Gila Project)	1-07-30-W0021	3/4/1952		278,000
Yuma County Water Users' Association (Valley Division, Yuma Project)	Water Rights Certificates 14-06-300-621	4/1/1957	Unquantified	
		Total: Priority 2 /3 Water Projects		528,000

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
Priority 2 / 3 – National Wildlife Refuges				
Cibola National Wildlife Refuge	Secretarial Reservation	8/21/1964	34,500	16,793
Havasu National Wildlife Refuge	1964 Supreme Court Decree	1/21/1941 2/11/1949	41,839	37,339
Imperial National Wildlife Refuge	1964 Supreme Court Decree	2/14/1941	28,000	23,000
		Total: Priority 2 /3 Refuges	104,339	77,132
Priority 2 / 3 – Others				
University of Arizona	14-06-300-144	1/1/1954	1,088	
Camille, Alec Jr.	14-06-303-528	12/23/1953	120	
Department of the Army – Yuma Proving Ground *(ADWR Recommendation)*			1,129	
Desert Lawn Memorial Park Association	14-06-303-1079	5/1/1956	200	
Gila Monster Farms	6-07-30-W0337	1/1/1952	6,285	
Kaman, Inc.	14-06-303-1555	12/21/1959	2	
South Pacific Company (now Union Pacific)	14-06-303-1524	12/21/1959	48	
City of Yuma	14-06-W-106	11/12/1959		48,522
City of Yuma (Cemetery)	14-06-303-1078	5/1/1956	60	
Yuma Mesa Fruit Growers Association	14-06-303-1196	1/1/1956	15	
Yuma Union High School	14-06-303-179	5/3/1960	200	
		Total: Priority 2 /3 Others	9,147	48,522
PRIORITY 4				
Priority 4 – Municipal and Industrial				
Arizona-American Water Company (Lake Havasu)	00-XX-30-W0391	1/23/2001	1,420	
Arizona State Parks Board / Windsor Beach	7-07-30-W0364	8/17/1998	90	
Brooke Water LLC	4-07-30-W0042	11/9/1983	320	
Bullhead City	2-07-30-W0273	11/9/1994	15,210	
Crystal Beach Water Conservation District	6-07-30-W0352	11/21/1997	132	
Desert Lawn Memorial Park Association	14-06-300-2587	5/30/1975	360	
Ehrenberg Improvement Assoc	8-07-30-W0006	10/14/1977	500	

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
Gold Dome Mining Company	0-07-30-W0250	6/6/1990	7	
Gold Standard Mines Corporation	3-07-30-W0038	8/25/1983	75	
Golden Shores Water Conservation Dist	9-07-30-W0203	6/1/1989	2,000	
Hillcrest Water Co	5-07-30-W0078	3/8/1985	84	
Lake Havasu City	3-07-30-W0039	10/4/1995	19,180	
Marble Canyon Company, Inc.	5-07-30-W0322	5/1/1996	70	
McCallister, Maurice L.	7-07-30-W0355	7/31/1998	40	
Mohave County Water Authority (subcontracted to: Lake Havasu City [6,000], Bullhead City [6,000], Mohave Water Conservation District [3,000])	5-07-30-W0320	11/14/1968	15,000	
Mohave Valley Irrigation and Drainage District	14-06-W-204	11/14/1968	5,000	
Mohave Water Conservation Dist	9-07-30-W0012	11/14/1968	1,800	
Town of Parker	2-07-30-W0025	1/6/1998	1,030	
Town of Quartzsite	7-07-30-W0353	1/28/1999	1,070	
Roy, Edward P.	9-07-30-W0124	2/24/1986	1	
Smucker Park	14-06-303-2702	11/21/1969	33	
US Bureau of Land Management	Secretarial Reservations (see 8-07-30-W0373)	8/30/1973 9/29/1981 4/27/1987		4,010
Verizon California, Inc (formerly Continental Telephone of California)	14-06-300-2506	2/5/1974	1	
Water Reserved by the Secretary of Interior for use in Indian Settlements			*3,500*	
		Total: Priority 4 Municipal and Industrial	**66,923**	**4,010**
Priority 4 – Municipal and Industrial pending Contracts				
Arizona State Land Department			1,534	
Arizona State Parks Board – Contact Point			20	
Brooke Water LLC			120	
Fisher Landing Water and Sewer			53	

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
Martinez Lake cabin sites			23	
Shepard Water Co			50	
City of Somerton			750	
Total: Priority 4 Municipal and Industrial Pending Contracts			2,550	
Priority 4 – Agricultural				
Cibola Valley Irrigation and Drainage District	2-07-30-W0028	1/31/1983	24,120	
Cocopah Indian Reservation	Supreme Court Decree	6/24/1974	2,026	
Curtis, Armon	3-07-30-W0037	8/29/1983	300	
Dulin Farms (has 2,016 af which goes to: Curtis family Trust [936] and Jessen Family Limited Partnership [1,080])				
Gila Monster Farms	6-07-30-W0337	7/28/1997	1,435	
Mohave Valley Irrigation and Drainage Dist	14-06-W-204	11/14/1968	30,060	
North Baja LLC (formerly Jamar Produce)	5-07-30-W0066	12/3/1984	480	
Pasquinelli	5-07-30-W0065	3/27/2003	486	
Raynor (Rayner) Ranches	5-07-30-W0064	10/29/1984	4,500	
Total: Priority 4 Agricultural			70,014	
Priority 4 – Agricultural Pending Contracts				
Curtis Family Trust			2,100	
El Cajon Farming (formerly Cameron Brothers)			1,290	
GoBo Farms (leased by Sunkist Growers)			924	
Jessen Family Limited Partnership (formerly Dulin Farms – Gleason portion)			1,080	
Ogram Farms			480	
Peach, John (formerly Bruce Church)			456	
Phillips, Milton and Jean			18	
Total: Priority 4 Agricultural Pending Contracts			6,348	

Entity	Contract Number	Priority Date(s)	Diversion Entitlement (Acre-Feet)	Consumptive Use Entitlement (Acre-Feet)
PRIORITY 5 AND/OR 6				
Gila Monster Farms			656	
Arizona-American Water Co (Havasu)			750	
Crystal Beach Water Conservation Dist			Unspecified	
Lake Havasu City			Unspecified	
Marble Canyon Corporation			Unspecified	
Mohave County Water Authority			3,500	
Mohave valley Irrigation and Drainage Dist			600	
Town of Parker			2,000	
		Total: Priority 5/6	7,506	

Appendix VI
WORKGROUP REPORTS – MONITORING COMMITTEE

ARIZONA DROUGHT MONITORING
Monitoring Committee Report 09-23-04

Introduction
Drought monitoring, and the ability to predict the current and future stages of drought development are key to drought preparedness planning. Various state and federal agencies operate a variety of data-gathering sites to supply real-time precipitation, streamflow, aquifer, and reservoir information to water-planning professionals. Taking a proactive approach to drought management requires continuous monitoring of factors indicating the onset and extent of drought conditions. This approach serves to lessen the element of surprise and allows time for planning and implementing drought mitigation strategies. Monitoring provides continuous feedback to decision-makers and helps determine the short-term planning for assessment and response actions.

Drought monitoring for Arizona will be accomplished through the efforts of the Monitoring Technical Committee (MTC), which is comprised of water resources, weather, and climate professionals from federal and state agencies, as well as the private sector and universities. The group is responsible for monitoring hydrological and climatological conditions, and analyzing other pertinent information necessary to determine the current status of drought conditions in Arizona. The group also reviews and reports on long-term forecasts to assist Arizonans in their drought preparedness and response actions. As necessary, the MTC will issue alerts based on various stages of drought that will trigger actions specified in the operational drought plan.

Purpose
The climate and topography of Arizona are quite diverse. Accordingly, various segments of the state's population can simultaneously be impacted by hydroclimatological conditions in different ways. For example, ranchers and other residents in rural areas, might be severely impacted by a significant lack of precipitation, due to dependence on groundwater and limited local surface water supplies. At the same time, residents in urban areas *might not be impacted* by the same lack of precipitation, because their water supply is provided water in reservoirs located both in Arizona, and out of state. Similarly, depending upon recent and past hydrometeorological conditions, different regions in rural areas might be experiencing vastly different drought conditions. The purpose of the MTC is to provide a current assessment of drought conditions throughout Arizona by continually monitoring various data and comparing these data to "trigger" values that could initiate actions or responses from various agencies.

Background
Drought is commonly defined simply as a lack of water. However, closer scrutiny of the phenomenon shows that various sectors are affected by drought in different ways, depending upon exposure to water shortage, as well as the time scales during which water deficits accumulate. The MTC has defined drought from short- and long-term perspectives. In Arizona, short-term drought can manifest in as little as a season (e.g., a dry winter), with effects on sectors that depend strictly on precipitation, and which have no recourse to supplemental water supplies. Examples of sectors particularly vulnerable to

short-term drought are ranching and wildlife management. Long-term drought might take as long as from one to several years to manifest, with effects on streamflow in perennial rivers, water supply, and the sectors that depend on them. In conjunction with these perspectives, specific values of selected data have been determined as "triggers" for action by various entities within Arizona. These trigger values will be closely monitored on a regional basis within the state. The initial regional boundaries that will be monitored are those described by the National Oceanic and Atmosphere Administration (NOAA) Climate Divisions for Arizona (see Figure 1).

Composition of the MTC

The Arizona Governor's Drought Task Force Monitoring Technical Committee (MTC) was formed during the summer of 2003. The MTC currently consists of representatives from state agencies (Arizona Department of Water Resources, Arizona Division of Emergency Management), federal agencies (National Weather Service, USGS Water Resources Division, USDA-NRCS), private agencies (Salt River Project), and universities (CLIMAS/University of Arizona, State Climatology Office/Arizona State University). The aforementioned representation of MTC members and organizations reflects interest and availability during 2003-2004. Once the core group was set, the MTC planning process was facilitated by the intimacy afforded by small committee size. The MTC recommends that membership be expanded to include many other agencies and organizations within Arizona. The Arizona Drought Preparedness Plan lists suggested organizations.

Definitions

Short-term Drought. Short-term drought is defined as the lack of precipitation as compared to a region-specific average amount for a duration sufficient to produce a *potential* hydrologic imbalance. Short-term_drought links characteristics of meteorological drought to rain-fed vegetation impacts, differences between actual and potential evapotranspiration, soil moisture, and seasonally- or annually-reduced groundwater and reservoir levels (including stock ponds). Short-term drought occurs when a combination of meteorological factors (e.g., temperature, precipitation, wind, sunshine) results in effects on key factors, such as soil moisture and evapotranspiration, that have the potential to impact vegetation. In Arizona, the vast majority of crop-based agriculture is assisted by irrigation, and is more susceptible to drought impacts on long timescales. Therefore, the MTC definition of short-term drought refers to rain-fed agriculture, ranching/forage production systems, and rain-fed ecosystems, which might show impacts on timescales of one season to one year.

Long-term Drought. Long-term drought refers to single- to multi-year precipitation shortages that result in deficiencies in surface and subsurface water supplies. It is measured in terms of long-term precipitation deficits, long-term indices of drought, streamflow (especially in perennial streams), and in lake, reservoir, and groundwater levels. Long-term drought is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). Long-term droughts are usually out of phase with or lag the occurrence of short-term droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and ground

water and reservoir levels. As a result, impacts to these elements of the hydrological system are out of phase with or lag other drought impacts.

Drought category. A drought category is a qualitative description of a level of drought severity, such as mild, moderate, severe, extreme, exceptional.

Drought indicator. A drought indicator is an observed quantitative or qualitative parameter, (such as precipitation, streamflow, soil moisture, groundwater level, reservoir storage), or a variable (such as a derived drought index), used to identify and assess drought conditions.

Drought trigger. A drought indicator is a threshold value of a drought indicator that distinguishes a drought category, and determines when drought mitigation or response actions should begin or end.

An example of how the aforementioned three terms can be interpreted: for an *indicator* of "streamflow," a drought *trigger* could be "streamflow below the 5th percentile for one month," which could then invoke the *category* of "extreme drought," and a corresponding set of management responses (Steinemann, 2003).

Monitoring and Assessment Plans

In order to meet Governor Napolitano's deadline for a completed drought plan and operational drought monitoring effort, the MTC has developed a flexible approach to drought monitoring, with short-, medium-, and long-term goals that employ various combinations of quantitative and subjective methods of drought monitoring.

Short-term plans

In order to meet short-term goals of providing drought monitor reports to the Governor by summer 2004, the MTC has adopted a model based on the U.S. Drought Monitor (USDM) process. The MTC implementation of this process involves the following: (a) monitoring of objective meteorological and hydrological parameters, (b) monitoring of objective and subjective rangeland and ecosystem parameters, (c) comparison of the aforementioned parameters to known historical measures of these parameters, (d) using expert statewide and regional judgment, subjective combination of the aforementioned into a drought status report at the NOAA climate division-level of geographic specificity, (e) preparation of drought status maps for the three drought levels defined in the introduction. In addition, to enhance adaptive capacity, the MTC will monitor predictors of future weather, climate, and water supply.

1. Monitoring objective meteorological and hydrological parameters
    a. Temperature and precipitation
        i. Sources: NOAA-NWS, National Climatic Day Center (NCDC), Office of the State Climatologist, Western Regional Climate Center
    b. Drought indices (PDSI, PHDI, SPI, SWSI)
        i. Sources: NCDC, Office of the State Climatologist, Western Regional Climate Center, USDA-NRCS
    c. Snowpack

i. Sources: USDA-NRCS

d. Reservoir levels

i. Sources: Salt River Project, USDA-NRCS National Water & Climate Center

e. Streamflow levels

i. Sources: USGS

f. Groundwater levels

i. Sources: Arizona Department of Water Resources, USGS

2. Monitoring objective and subjective rangeland and ecosystem parameters

a. Satellite vegetation health index

ii. Sources: NOAA-NESDIS (http://www.orbit.nesdis.noaa.gov/smcd/emcb/vci/)

b. Vegetation greenness indices

i. Sources: USDA-Forest Service Wildland Fire Assessment System (http://www.fs.fed.us/land/wfas/)

c. Fire danger rating and fuel moisture status

i. Sources: USDA-Forest Service Wildland Fire Assessment System (http://www.fs.fed.us/land/wfas/)

d. Ranching conservation, ecosystem, topsoil, and agricultural conditions

i. Sources: USDA-NRCS, AZ Department of Agriculture, University of Arizona Cooperative Extension, Arizona Department of Game & Fish

3. Monitoring predictors of weather, climate, and water supply

a. Seasonal climate and medium-term weather outlooks

i. Sources: NOAA-CPC, International Research Institute for Climate Prediction (IRI)

b. Water supply forecasts

i. USDA-NRCS National Water & Climate Center

ii. NOAA Colorado Basin River Forecast Center

iii. US Bureau of Reclamation

c. Atmospheric circulation patterns (ENSO, PNA, NAO, PDO, etc.)

i. NOAA-CPC, IRI, JISAO

Medium-term plans

The MTC medium-term drought monitoring strategy is to create an operational system to monitor drought on multiple time scales at a minimum spatial resolution of the NOAA climate divisions. The latter is expedient, though far from ideal, given the local scales at which drought mitigation and response decisions must be made. The MTC will monitor drought indicators at short, and long time scales. Drought indicators for use in the numerical drought triggers have been selected from those previously mentioned. Based on statistical analyses, the need for high-quality, complete, long-term indicator data with monthly-resolution, and the expert opinions of MTC members, a select group of drought indicators will be used to trigger climate-division level drought status. The procedure for determining the select group of drought indicators is described below in this section entitled Analytic Procedures to Calculate Triggers.

Long-term plans

In the long-term, the MTC will develop drought monitoring and drought status reporting a county-or-smaller spatial scale. This scale of reporting is necessary to account for Arizona's diverse topography and associated spatial data gaps, as well as the shortcomings (such as averaging data from high and low elevations) of the NOAA climate division dataset. This will require standard analyses of hydroclimatic data at individual locations, and the use of new interpolated data products for which retrospective historical data series have

been developed. Such datasets are also required in order to create a baseline for incorporating the short-term records of stations that are installed in order to complement spatial gaps in existing data networks. Monitoring drought and reporting drought status on a county-or-smaller spatial scale will require determination of new drought triggers to match the appropriate spatial scales. Moreover, the MTC will conduct annual evaluations of the performance and effectiveness of the drought indicators and the trigger system. This kind of effort is in keeping with the guiding philosophy of this drought plan, namely that the planning process needs to be ongoing in order to respond to changing conditions and improved information.

In order to take advantage of extensive paleoclimate records of Arizona drought and precipitation variations, the MTC intends to develop alternative records of drought history, severity, and duration for drought monitoring. Such alternative records will provide additional perspective on drought in Arizona.

Drought Monitoring Data and Data Needs

F. Data Availability and Gaps

Precipitation, Temperature, and Drought Indices (Contributed by the State Climatologist, NWS Phoenix, and USDA-NRCS)
Ultimately, drought conditions of any type can be traced to the sole natural moisture input to the hydrologic cycle- precipitation. Likewise, a good measure of the overriding natural removal of water from a hydrologic system is the potential for evaporation, for which the surrogate of air temperature is most often used. Fortunately for drought monitoring, air temperature and precipitation are the two most commonly measured climatic variables. Often these two parameters are combined to produce relative measures of drought. Discussed in this section are the availability, the processing, and the needs associated with the temperature, precipitation, and drought index data that are employed by the Monitoring Technical Committee (MTC).

<u>Precipitation</u>
Ideally, a dense and uniform distribution of individual stations at which precipitation is measured daily would be maintained for high resolution drought monitoring. However, lack of data at small scales, and the onerous process of accounting for missing data and assuring data quality, makes this a difficult objective for the MTC initially. In order to create a manageable volume of data, monthly precipitation data are used rather than daily data. As drought conditions are relatively slow to evolve, especially in the western U.S., monthly data should be effective at capturing the changing physical conditions. For the purposes of monitoring, daily data may simply complicate the picture of a slowly evolving and retreating phenomenon, such as drought. To avoid station distribution and data quality problems, a prepared dataset from the National Climatic Data Center (NCDC) set is being employed by the MTC. Monthly precipitation values are taken from the climate division dataset, which is comprised of monthly averages created from data for individual stations falling within climatically homogeneous regions within each of the 48 contiguous states of the U.S. Within Arizona, there are 7 such climatic regions, consisting of single- and multi-county units (Figure 1). For each region, there exists a monthly average precipitation value across the period 1895-present. The data are quality assured through

data processing techniques at NCDC, and the product is a spatially and temporally continuous data set that is updated from station data within the first 1-2 weeks of each month (<http://www.cdc.noaa.gov/Timeseries/>). A feature of the database is the inclusion of a statewide average monthly value created from the data for each climate division within the state, weighted by the area of each division. Thus, it is rather straightforward for the MTC to confidently update precipitation within defined climatic regions and for the state as a whole on a monthly basis within the first 2 weeks of each month.

Arizona Station Precipitation Data

A user-friendly web-based presentation of precipitation values from individual stations throughout Arizona, from 1996 to the present has been made available to the public on me National Weather Service Phoenix Forecast Office web site. As of March 2004 the URL for this web site is:
http://www.wrh.noaa.gov/cgi-bin/Phoenix/DroughtPage.pl?data=ALLDATA

The database was created from a combination of National Weather Service (NWS) First Order and NWS Cooperative Observer Stations. Each station was scrutinized for completeness and data accuracy. It is rare to find 100% serially complete weather records; therefore, great care has been taken to include in the database those stations that have only minimal amounts of missing data. In the estimation of NWS personnel, these data are highly reliable. Great care was taken to eliminate stations with much missing data and/or poor quality data; therefore, any first order or cooperative station not included was determined to have inaccurate or incomplete data sometime during the 1996-2003 time frame. The 1996-2003 time frame was chosen to be representative of the recent drought. There are 81 Arizona stations included in the NWS database.

In addition, the web site provides information about the difference between recent precipitation and the long-term average precipitation. The database will be updated each month around the 15th. For example, February data will appear in the current year's column around March 15th. Stations not reporting by the 15th will be updated as the data become available. These data will be used by the MTC to examine sub-climate division drought variations, and to corroborate the "big picture" drought status portrayed by climate division data.

Temperature

Even more spatially continuous than precipitation is the climatic variable average air temperature. The climate division database of NCDC includes average monthly temperature for each of the 7 climatic regions within the state of Arizona. The data are quality assured and published on the same schedule as the precipitation data. Used only as a loose indicator of water demand in the form open-water evaporation and potential evapotranspiration from land surfaces, and consequently, municipal demand, average air temperature is represented in the same way as precipitation. Data for each climate division and a statewide average are placed into a historical context in the form of a frequency distribution for 1-, 3-, 6-, and 12-month periods. As with precipitation, average air temperature can be monitored rather easily and updated within the first 1-2 weeks of each month.

Palmer Drought Severity Index

Another product of the NCDC climate division database is the calculation of a drought index from monthly precipitation and average monthly air temperature. The Palmer Drought Severity Index (PDSI) was developed during the early 1960s as a method for quantifying drought conditions (for more information, see Palmer, 1965 and http://nadss.unl.edu/pdsi/doc/index.html). The PDSI actually uses a supply and demand model for the amount of moisture in the soil. The value of the PDSI is reflective of the how the soil moisture compares with normal conditions. A given PDSI value is usually a combination of the current conditions and the previous PDSI value, so the PDSI also reflects the progression of trends, whether it is a drought or a wet spell. Consequently, PDSI is best used in for diagnostic, or historical, analyses, rather than for operational, or current monitoring, analyses.

Palmer derived arbitrary PDSI categories, which range from "mild" to "moderate" to "severe" to "extreme". The normal range of PDSI values are from -0.50 to +0.50. Any PDSI values above +4.00 or below -4.00 fall into the "extreme" category of a wet spell or drought. The PDSI is based around a supply and demand model of the soil moisture at a location. The supply is the amount of moisture in the soil plus the amount that is absorbed into the soil from rainfall. The demand is based upon the potential for water loss from the soil to the atmosphere and is largely dependent upon air temperature. However, Palmer derived his index based on a limited sampling of weather stations, chiefly from the relatively flat Midwestern U.S. There is good reason to believe that Palmer's categories do not correspond well to conditions in Arizona. MTC analyses show that the distribution of PDSI data for Arizona is highly skewed, therefore, undesirable for the drought trigger system developed by the MTC. The MTC favors the Standardized Precipitation Index (see below) for drought monitoring in Arizona. Nevertheless, the MTC will consult PDSI data, as agriculturalists and others still frequently use it.

The NCDC climate division database includes monthly PDSI values for each climatic region and for the state of Arizona as calculated from the monthly precipitation and temperature data discussed above. As part of the NCDC climate division product, PDSI can be rather easily monitored and updated quickly for each month.

Climatic Water Budget

The Office of the State Climatologist for Arizona uses a model for calculating soil moisture surplus/deficit from monthly climate division values of temperature on precipitation. The outputs of the model provided another exceedingly useful measure for monitoring drought.

Standardized Precipitation Index

As monthly precipitation data are updated, the current month is placed in a historical context by locating the magnitude within a frequency distribution for the full period of record. In other words, the data are ranked and the ranking is divided by the period length in order to place the current month into perspective. The same procedure is followed for the most recent 3-, 6-, 12-, 24-, 36-, and 48-month periods, based on precipitation totals for each of those periods. In addition, what is referred to as the Standardized Precipitation Index (SPI) is calculated for each climate division, and for the statewide average, on a monthly basis and for the 4 intra-annual periods. The SPI is a relatively new drought index based only on precipitation. The SPI can be used to monitor

conditions on a variety of time scales. This temporal flexibility allows the SPI to be useful in both short-term agricultural and long-term hydrological applications. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a Gamma probability distribution, which is then transformed into a Normal distribution so that the average SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. Moreover, the SPI is calculated in a way that facilitates direct comparisons of drought conditions between regions with great differences in climate.

Surface Water Supply Index

In 2004, the NRCS began calculating an experimental Surface Water Supply Index (SWSI) for Arizona river basins. The SWSI complements drought indices that require only climatological inputs, such as the PDSI and SPI, because it incorporates hydrological and climatological inputs into a single index. The SWSI calculation is based on the following four input variables: historic snowpack, mountain precipitation, streamflow, and reservoir storage data collected from individual watersheds. The SWSI is an indicator of surface water conditions in regions where mountain snowpack is a major component; in Arizona, such regions include the high elevations of northern Arizona, along the Mogollon Rim, and throughout the sky island mountain ranges of southeastern Arizona. The SWSI is useful in anticipating water availability for irrigated agriculture, fisheries, and other uses of runoff water. The SWSI can be used to anticipate post-winter water supplies since the water content of snowpack is stored until runoff. Like the PDSI, the SWSI is centered on zero and ranges from +4.2 to - 4.2, as shown in Table 1.

Table 1. Surface Water Supply Index (SWSI) Designations

SWSI value range	Qualitative description
+3.0 to +4.0	Extremely wet
+2.0 to +3.0	Moderately wet
+1.0 to +2.0	Slightly wet
-1.0 to +1.0	Near average
-1.0 to -2.0	Slightly dry
-2.0 to -3.0	Moderately dry
-3.0 to -4.0	Extremely dry

Data Needs

As stated at the outset of this discussion, ultimately it may be most beneficial to monitor sub-regional and local-scale data from the several hundred individual stations across Arizona. The utility of this approach is debatable, as there are issues regarding processing this vast volume of data, assuring data quality, and factoring in problems associated with station distribution and density. At present, the MTC recommends that the assurance provided by the climate division database and the ease with which it can be smoothly incorporated into a monitoring program far outweigh problems associated with the lack of fine spatial resolution. As greater resources for climatic monitoring become available for the state of Arizona, it may well be worth exploring the option of using

point data for assessing statewide drought status. However, at the outset of this process the data described above seem to be sufficient.

Once a level of drought status has been triggered by climate division-scale monitoring analyses provided by the GDTF MTC, data from individual stations will be used to assess the need for drought mitigation and response actions at the local levels necessary for implementing those actions, and to corroborate the drought status portrayed by the climate division data. The MTC has identified the following gaps in Arizona's Climate data monitoring network:

(1) Additional stations are needed in order to provide sufficient station density and spatial data homogeneity; the highest priority needs for additional climate/weather monitoring stations to improve station density include northwestern and northeastern Arizona

(2) High-altitude temperature and precipitation data are sorely lacking throughout the western U.S. Since the distribution of precipitation in Arizona is highly dependent on altitude, and because Arizona water supplies are highly dependent on snow accumulated during winter months, the addition of mountaintop stations, especially in snow-bearing regions, is crucial.

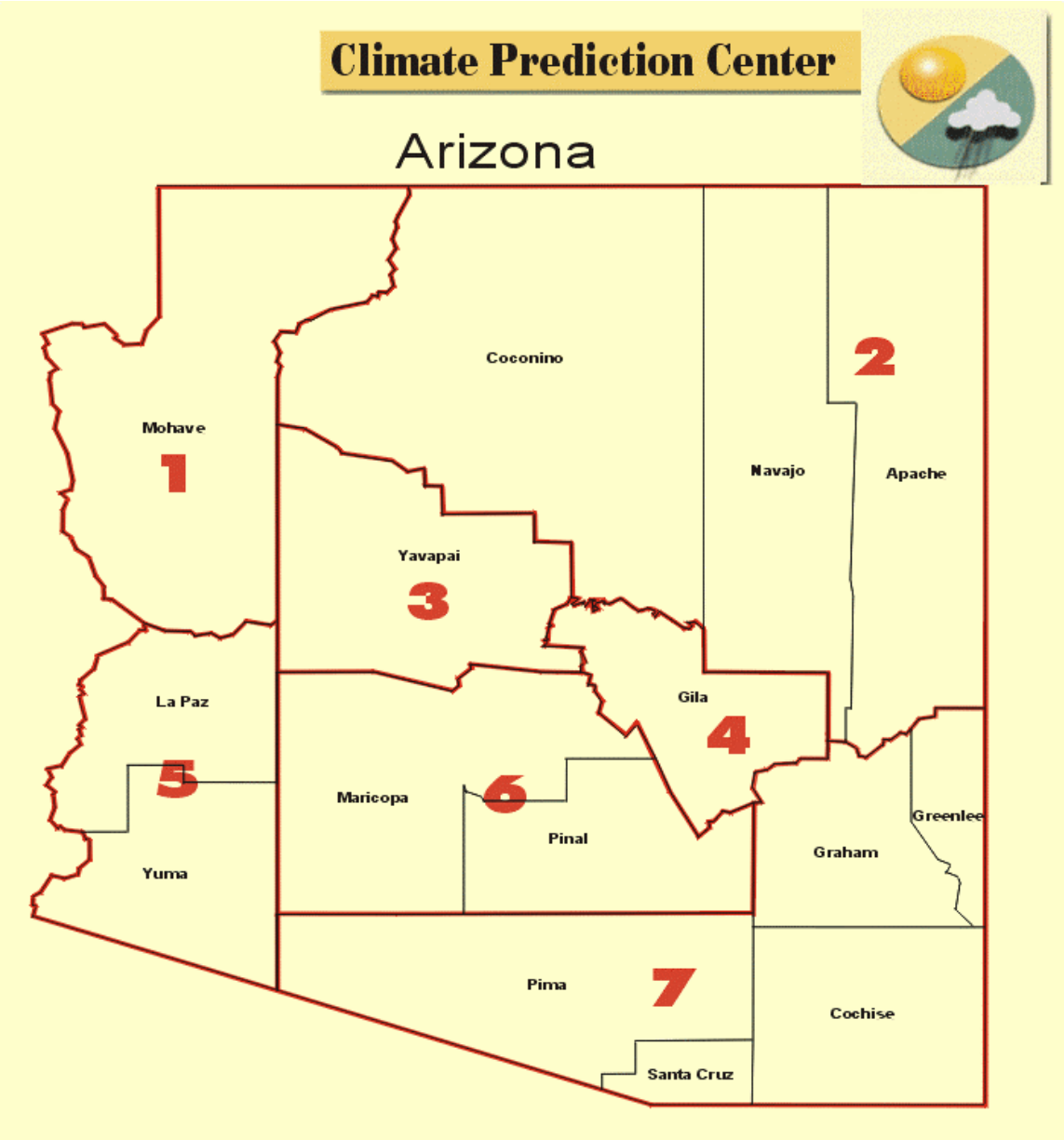

Figure 1. Arizona climate divisions (numbered -- red outlines) and counties. Source: NOAA Climate Prediction Center.

Snow (Contributed by USDA-NRCS)

The Natural Resources Conservation Service (NRCS) provides leadership in a partnership effort to help people conserve, maintain, and improve our natural resources and environment.

Ongoing Activities

1. Collect and maintain records on snow depth, snow water content, water year precipitation, and air temperature at 15 fully automated SNOTEL (SNOw

TELemetry) sites (Figure 2). These sites provide data one reading per day. Data can be collected more frequently if the need is warranted. Twelve of the sites have records from 1983 to present; 3 have records from 1995 to present. The relatively short length of SNOTEL records requires that these data be used only to corroborate drought status.

2. Project spring runoff volumes based on measurements of mountain snowpacks, monthly precipitation, monthly streamflow, and statistical analysis of historic hydroclimatic data, collected and kept for key river basins.

3. Compute Surface Water Supply Index (SWSI) values for the Salt, Verde, and Upper Gila River Basins. The calculation of the SWSI relies on input of current snow, streamflow, precipitation, and reservoir storage data along with statistics generated from historic data kept for each river basin. An Excel template is used to process the basic data elements necessary to calculate the SWSI. Values are produced January-April each year. In several western states, the SWSI is used as an indicator of drought severity. As the SWSI product is new, the MTC will evaluate the use of SWSI as a drought indicator.

4. Produce an Arizona Basin Outlook Report each winter on the 1st and 15th of each month, beginning January 1 and ending with the April 1 issue. The report provides snow survey data and seasonal water supply forecasts in a graphic, tabular, and narrative form for use by the public. In dry years, the data contained in the report often serves as the first indicator of drought for the coming season. The MTC will consult Basin Outlook Reports, in conjunction with evaluating monthly trigger-based drought status.

5. Provide conservation technical assistance to the agricultural community for installation of conservation practices and measures for the purpose of water conservation, water quality improvement, erosion control and prevention, proper grazing use, and similar conservation measures.

6. Provide snow survey data, seasonal water supply forecasts, SWSI values, and soil and water conservation planning information online from the NRCS home page at http://www.az.nrcs.usda.gov/snow/.

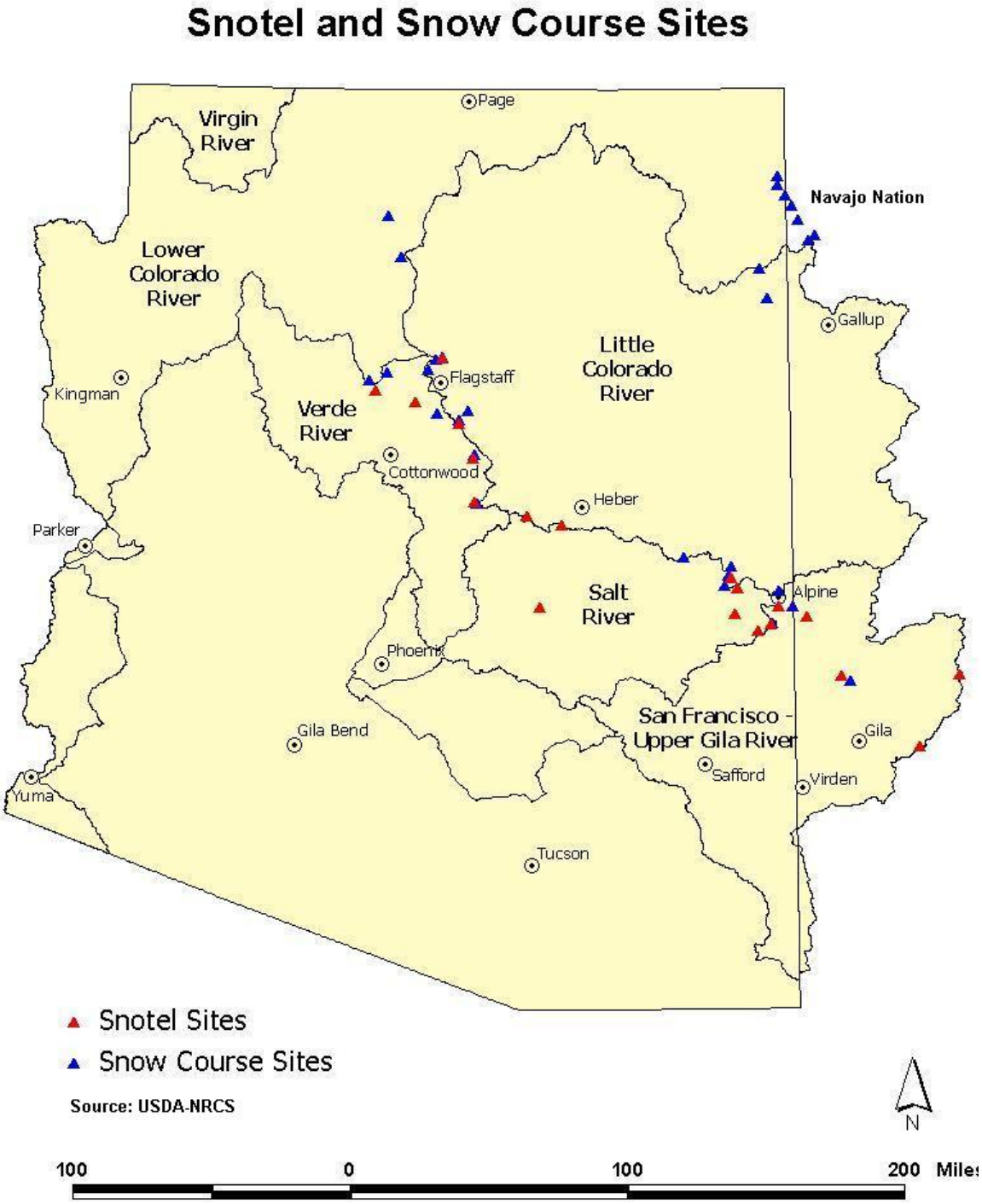

Figure 2. Arizona and western New Mexico SNOTEL and snow course sites. Source: USDA-NRCS.

Reservoirs and Lakes (Contributed by USDA-NRCS and USGS)

The Salt River Project

The Salt River Project (SRP) is the first multipurpose project authorized under the Federal Reclamation Act of 1902. The 13,000 square-mile watershed supplies water to an area of about 240,000 acres in Maricopa County, AZ. The Salt River Project Agricultural Improvement and Power District and the Salt River Valley Water Users' Association operate the dams and related facilities, which together form the SRP, an organization managed by landowners located within the project area. Private landowners funded construction of the original project in the 1890's. Irrigated agriculture began in the 1860's and led to the development of the town of Phoenix. Earliest know irrigated agriculture dates back to 200 B.C., when the Hohokam people built 125 miles of earthen canals to divert water from the Salt River.

The SRP reservoir system includes four dams on the Salt River, two on the Verde River and one below the confluence of the Salt and Verde Rivers. There are about 1,295 miles of canals, laterals and ditches in the delivery system.

Table 2. Salt River Project Reservoir System.

Name	**Year completed**	**Water storage capacity (acre-feet)**
Salt River		
Roosevelt Lake (Theodore Roosevelt Dam)	1911	1,653,043
Mormon Flat Dam (Canyon)	1925	57,852
Horse Mesa Dam (Apache)	1927	245,138
Steward Mountain Dam (Saguaro)	1930	69,765
Verde River		
Bartlett Dam	1939	178,186
Horseshoe Dam	1946	109,217
Confluence		
Granite Reef Diversion Dam	1908	0
Total		**2,313,201**

Note: Salt River Project provides water supply information on-line at http://www.srpnet.com

Granite Reef Diversion Dam was built about 50 miles downstream from Roosevelt Dam. Its purpose is to divert water released from the Verde and Salt Rivers into the north side and south side canals for ultimate delivery to water users.

The SRP water storage and distribution facilities were constructed to deliver water to irrigable lands and to the Phoenix townsite. The project now supplies the City of Phoenix with a major part of its water supply. The cities of Glendale, Scottsdale, Tempe, Mesa, and Chandler have contracts whereby the cities pay to the SRP the irrigable water assessment for urban acreage that is no longer in agriculture. More than 100,000 acres of the original 240,000 acres of irrigable land have been urbanized.

The elevation of the project area ranges from 1,300 to over 12,000 feet. The agricultural area is a semi desert; mean annual precipitation is 7.5 inches, so that irrigation is a necessity. Annual use of irrigation water is 3 acre-feet per acre. Mean annual temperature is near 72°F, which allows for year-round crop production.

Soils of the project consist of various alluvial loams, with some pockets clay soils, that are generally deep and fertile. Principle crops grown are alfalfa, grains, cotton, citrus fruit, and vegetables. Sorghum and corn silage are popular second crops for multiple cropping.

Colorado River System

The Colorado River begins in the mountains of north central Colorado near the community of Granby, CO, and flows southwest 1,400 miles to the Gulf of California. The river and its tributaries, the Green, Gunnison, San Juan, Virgin, Little Colorado, and the Gila Rivers, are referred to as the "Colorado River Basin." These rivers drain one-twelfth of the continental land area in the western U.S., or about 242,000 square miles, and an additional 2,000 square miles in Mexico. The Colorado River serves an estimated 24 million people in seven basin States: Colorado, New Mexico, Utah, Wyoming, California, Arizona, and Nevada.

In 1922, a Colorado River Compact provided for apportionment of Colorado River water equally between Upper and Lower Basin states, with the division point set at Lee's Ferry, located in northern Arizona about 30 miles south of the Arizona-Utah border. New Mexico, Colorado, Utah, and Wyoming were designated Upper Basin states and Arizona, Nevada, and California Lower Basin states.

The 1922 Compact apportioned to each basin the exclusive, beneficial consumptive use of 7.5 million acre-feet (maf) of water per year from the Colorado system in perpetuity. The Compact, however, did not apportion water to any state.

In 1948, the states of the upper division entered into the Upper Colorado River Basin Compact, which apportioned waters among the upper division states. The Compact, among other things, permitted Arizona to use 50,000 acre-feet (af) of water annually from the Upper Colorado system, because a portion of the state is within the Upper Basin; and apportioned the remaining water to the Upper Basin States in the following percentages: Colorado 51.75% (3.86 maf), New Mexico 11.25% (843,750 af), Utah 23% (1.71 maf), and Wyoming 14% (1.04 maf).

The Lower Basin states of Arizona, California, and Nevada were unable to reach agreement on apportionment and, in 1952, Arizona asked the U.S. Supreme Court for judicial apportionment. As a result, in 1962, the Court ruled in *Arizona v. California* that of the first 7.5 maf of mainstem water in the Lower Basin, California is entitled to 4.4 maf, Arizona 2.8 maf, and Nevada 300,000 af, with each state also awarded all the water in their tributaries.

The Upper Colorado River Basin Compact of 1948 also served to set the stage for passage of the Colorado River Storage Act of 1956, by Congress. Among other things, the act provided for federal authority to build a series of storage reservoirs in the Upper Basin that will help the upper division states meet their obligation to the lower division states of 7.5 maf of water per year. As a result, the act facilitated the construction of Glen Canyon Dam on the Colorado River in Arizona, Flaming Gore Reservoir on the Green River in Utah, Navajo Reservoir on the San Juan River in New Mexico, and Crystal, Morrow Point, and Blue Mesa Reservoirs on the Gunnison River in western Colorado.

At present, the entire system of reservoirs on both the upper and lower divisions of the Colorado River can hold an estimated 60 maf of water, or about 4 times the annual basin inflow based on an annual average of 15 maf.

Table 3. Colorado River Reservoirs that border Arizona.
Colorado River Storage/Arizona

Name	**Year completed**	**Water storage capacity (acre-feet)**
Lake Powell (Glen Canyon Dam)	1963	24,322,000
Lake Mead (Hoover Dam)	1935	26,159,000
Lake Mohave (Davis Dam)	1958	1,810,000
Lake Havasu (Parker Dam)	1938	619,400
Total		**52,910,400**

Note: The U.S. Bureau of Reclamation provides water supply and operations information on-line at http://www.lc.usbr.gov

Small Lakes and Impoundments (contributed by USGS, Flagstaff)

Upper Lake Mary Reservoir, City of Flagstaff.
Upper Lake Mary Reservoir has been an important water resource for the City of Flagstaff since the Dam was completed in 1941. The crest of Upper Lake Mary Dam was raised 10 feet in 1951 providing for a total storage capacity of 15,600 acre-feet (5,083,000,000 gallons). Upper Lake Mary is currently one of five water resources developed by the City of Flagstaff to meet the water demand for the community and surrounding area. The other four sources of water supply for the City of Flagstaff are: 1. Water from the Inner Basin of San Francisco Mountain, 2. Ground water from wells in the Woody Mountain Well Field, 3. Ground water from wells in the Lake Mary Well Field, and 4. Ground water from recently developed Inner City wells. The City of Flagstaff also has an active water conservation program that utilized an inverted rate structure, mandatory water conservation triggered by critical water supply indicators, and a water re-use program to supplement the use of fresh water around the city for golf courses, parks, and ball fields. By agreement with the National Forest Service the City of Flagstaff quits drawing water from the Lake when the capacity drops below 17 percent. From 1960 to present this has happened 10 times, 4 since 2000.

The City of Flagstaff first developed a water supply from the springs in the Inner Basin in the late 1890's and acquired rights to all of the water in the Inner Basin by 1925. The City of Flagstaff has continued to maintain and upgrade this source of water supply by developing additional springs and drilling wells. Currently, the Inner Basin, can supply about 300,000,000 gallons (920 acre-feet) on average during the summer months.

However since this water source is derived from perched water-bearing zones with relatively small storage they are susceptible to drought and not available to the City of Flagstaff as a source of water supply in dry years. Since 2000 the City of Flagstaff has only been able to develop 100,000,000 gallons or less from this resource.

As the drought in the 1950's dried up surface water resourced in the Flagstaff area. The City began a well drilling program that has continued to this day. The first well was drilled in the Woody Mountain Well field in 1954. A decade later, in 1963, the first well was drilled in the Lake Mary Well field. Currently there are 11 wells in the Woody Mountain Well field and 9 wells in the Lake Mary Well field that make up the bulk of the City of Flagstaff's water supply. All of these wells are developed in the regional C aquifer (Coconino aquifer) that, because of its large storage and regional extend, is less susceptible to long term droughts. The Woody Mountain Well Field has a current capacity of 5.6 million gallons per day (MGD) and the Lake Mary Well Field has a current capacity of 4.5 MGD. In the dry years in the late 1980's and in the current drought the City has been ever more dependent on its well fields to meet water demand for the community as the water supplies from Upper Lake Mary and the Inner Basin become less dependable. As a result of heavy use for the last two decades there have been water-level declines in the C aquifer of more that 100 feet in the Lake Mary area and about 50 feet in the Woody Mountain area.

In response to the recent drought in the late 1980's and the current drought, the City of Flagstaff has expanded its well drilling program to develop new wells in the Inner City area. It is hoped that development of new wells in the city limits of Flagstaff will help to offset the lack of water from Upper Lake Mary and the Inner Basin, and allow the City to provide some relief for the water deficit developing in the Lake Mary and Woody Mountain well fields. The City currently has developed 5 new wells in the Inner City area in the C aquifer. These wells will have a combined capacity of about 3.2 MGD when fully developed.

The current water use for the City of Flagstaff is about 10,500 acre-feet per year (2001) and supports all of the municipal and industrial water demands of the City. Water use from water companies surrounding Flagstaff that use C aquifer water as their only source of water supply amount to another 4,000 acre-feet per year primarily for public supply. In recent years the City of Flagstaff water conservation and reuse program has saved the city about 2,000 to 3,000 acre-feet per year of fresh water. Growth and development projection indicate that the population of the Flagstaff area will more that double over the next 45 years. This will result in an attendant demand for new water supplies of an additional 20,000 to 25,000 acre-feet per year. The City of Flagstaff plans to continue to develop wells in the C aquifer as it investigated the possibility of acquiring water right on the Lower Colorado River as a potential resource for the future.

References:

Flagstaff water history at URL: http://www.flagstaff.az.gov/index.asp?SID=323, accessed March 8, 2004.

City of Flagstaff Utilities Department Report to the Water Commission: Water and Wastewater Operation Plan year 2002, April 2002.

Rocky Mountain Institute, North Central Arizona Water Demand study, June 2002.

U.S. Geological Survey data and reports.

Surface Water Storage System, Williams, Arizona.
The City of Williams has historically depended on a series small surface water reservoirs and shallow low yield wells to meet the water demand for the community. The reservoirs are Dogtown, Kaibab, Cataract, City Dam, and Sante Fe. Sante Fe Dam was the first water storage facility completed in the Williams area by the Sante Fe Railroad in 1892. The Railroad also built the City Dam in the late 1890's to 1900. The storage capacity of Sante Fe reservoir was increased by the railroad in the 1920's. The City of Williams purchased Sante Fe and City Dam from the railroad in the late 1920's to 1930's as a source of water supply for the growing community. In the 1930's and 1940's Williams constructed three new dams: Dogtown, Kaibab, and Cataract. Dogtown reservoir is the largest of the five reservoirs with a capacity of 360,000,000 gallons (1,105 acre-feet). The others in order are: Kaibab Reservoir, 293,000,000 gallons (899 acre-feet), Cataract Reservoir, 135,000,000 gallons (414 acre-feet), Sante Fe Reservoir, 70,000,000 gallons (215 acre-feet), and City Dam, 36,000,000 (110 acre-feet). The total storage capacity of the City of Williams Reservoirs is 2,743 acre-feet. 1998 was the last year all of the reservoirs were full. The maximum contents for 2003 were 24 percent of capacity and that was the highest since 2000. Shallow wells, low yield wells in perched aquifers around town have been a source water for the community since the mid 1800's. But as the reservoir system developed these wells fell out of favor owing to their low yield and unreliability.

While the growth for the City of Williams has fluctuated in the past, since about the 1980 with the redevelopment of the Grand Canyon Railroad there has been slow but steady growth. Water use for the Community is entirely for public supply. In 2000 the annual water use for Williams was 794 acre-feet. As the community continues to experience slow but steady growth for the next 45 years the demand for new water may be another 1,200 acre-feet per year.

In the drought years of the 1950's, 1970's, and late 1980's the City of Williams had several close calls with its water supply, nearly running out on several occasions. In one case in the 1960's (?) a water train was put together to bring water from Del Rio Springs in Chino Valley to Williams. When the train arrived in Williams however, it was discovered that there was no plumbing available to unload the train. In spite of close calls like this the City of Williams has always managed to get by with it surface water supply.

After the drought in the late 1980's the City of Williams began to realize that its surface-water supply was going to no longer be adequate in light of continuing growth and the likelihood of more and longer droughts. As a result the City began a well development program that has led to the drilling of several deep water supply wells in and around town. The first well completed was a relatively shallow well downstream of Sante Fe Reservoir in the Kiabab Formation. While the well could produce about 100 gpm it was discovered that if pumped for more than a few weeks at a time it would dry up. Since then the City of Williams has had more success developing wells in the water-bearing zones in the Redwall and Muav Limestones at depths of greater than 3,000 feet below land surface. The first of these wells was Dogtown 1 completed in 1998 and capable or producing about 260 gpm. Since then the City of Williams has completed wells in town (the Rodeo well) in 2001, and Dogtown 3 in 2003. The combined capacity of Dogtown 1

and the rodeo well is about 775,000 gallons per day and has significantly improved the City's water outlook for the future. The Dogtown 3 well is currently awaiting a pump and infrastructure to complete.

References:

Rocky Mountain Institute, North Central Arizona Water Demand study, June 2002.
Dennis Wells, City Manager Williams, oral Communication., March 9, 2004).
U.S. Geological Survey data and reports.

Lyman Lake.

Lyman Lake is an irrigation storage reservoir on the Little Colorado River upstream of St Johns, Arizona with a capacity of about 30,600 acre-feet as of the late 1990's. Releases from Lyman Lake are fully allocated to downstream users, primarily the Lyman Lake Irrigation District and the St. Johns Irrigation District (Arizona State Superior Court, 1918). During the winter controlled releases generally are not made as the lake fills with runoff from the Little Colorado River. During the spring and summer water is released to Lyman Canal and the Little Colorado River through outlet works at the base of the dam. Lyman Lake is also used for recreation. The Lyman Lake State Park, the first State Park in Arizona, provides for a range of recreational activities including boating, fishing, sailing, and hiking.

Lyman Dam and Lyman Lake have had a rough past. The Dam was originally built in the mid-late 1900's and failed in late 1910 or early 1911. The dam was rebuilt in June of 1911 and failed again April 14, 1915. The Dam was rebuilt in 1920 and failed yet again in July of 1927. The 1927 breach sent a flood wave down the Little Colorado River that did considerable damage to the communities of St. Johns and Holbrook and stranded the USGS Birdseye Expedition on the Colorado River below Lava Falls for several days. The Dam was rebuilt again in 1929/30. The reason for the dam failures appears to be the location of the dam on top of a spring area. Since the dam was rebuilt in 1929/30 it has continued to leak. The Dam was declared one of the most hazardous in the state by ADWR in 1986/87 and was drained for repair in 1988/89. The repair was not wholly successful so Lyman Lake was maintained at less than half capacity for safety since the early 1990's. Lyman Dam was finally renovated and the crest and spillway raised about 10 feet (elevation is now 5,991.5 feet) in 2000/01. Current capacity of the lake is unknown. On March 10m 2004 the storage in the lake stood at 2,040 acre-feet or about 6.8 percent of capacity based on the old contents table.

Since the Dam was rebuilt in 1929 the Lake has spilled 6 times: April-May, 1932; April-May, 1941; April 1966; April-May, 1973; April-June, 1979, and April-May, 1980. Records of minimum contents are less precise but periods of low storage in the lake occurs from 1960 to 1963 and from1975 to 1978. Drought effects on Lyman Lake in the 1980's and 1990'2 cannot be determined owing to operation of the dam for safety.

References:

U.S. Geological Survey Annual Data Reports, 1978 and 1980.
Estimates of Ground-Water Flow Components for Lyman Lake, Apache County, Arizona, Bills and Others, 1990, U.S. Geological Survey Water-Resources Investigations Report 89-4151, 55 p.

Lyman Lake State Park History, Arizona State Parks Web site.
Lyman Dam Renovation, 2000/01,
URL:http://www.ecih2o.com/PROJECTS/DAMSSFTYproj/Lyman.html

Kingman and Northwestern Arizona.
Kingman, other small communities along I-40 and the Hualapai Reservation are entirely dependent on ground-water resources to meet the water demand of the area. Since the 1980's Kingman and the surrounding area has grown substantially. In particular, rural development in Sacramento Valley to the west of Kingman has expanded to support the rapidly growing resort facilities of Laughlin, Nevada just across the Colorado River. A new natural gas electricity generating plant was built in the Middle of Sacramento Valley and came on line in 2000. The plant uses groundwater as a source of cooling water. There is also continuing discussion on the trans-basin diversion of ground water to support a Copper Mine to the south. All of these activities have resulted in increasing groundwater declined in the various water-bearing zones in the unconsolidated sediments that support the municipal, public supply, and industrial water uses of the area.

Arizona Strip.
The Arizona Strip is probably one of the most sparsely populated areas of the State of Arizona. The principal community of Fredonia has a population of less than 5,000 and is primarily an agricultural based community. The Kaibab-Paiute Reservation to the west of Fredonia has a population base of less than 500 and is also agriculturally based. The principal sources of water for irrigation and public supply are Kanab Creek and spring in the area that discharge from the Navajo Sandstone respectively. A few wells also exist in the area for irrigation and domestic water supply. The minimum flow of 2.9 cfs on Kanab Creek occurred on July 27, 2000. Previous daily minimum of 3.0 cfs occurred in June, 1986. The Clinton Administration created two new National Monuments on the Arizona Strip: the Grand Canyon-Parashant and the Vermillion Cliffs. The addition of these two new National Monuments to the Arizona Strip, growth and development in the border areas of Utah and Nevada, and the potential of ground-water diversions to support coal mine operations in Utah and a power plant in Nevada will add water demand pressure to an already water poor landscape.

Groundwater (*Contributed by ADWR*)
The Arizona Department of Water Resources maintains a groundwater level monitoring network of approximately 1500 index wells. These wells have, at a minimum, annual measurements with an average length of record of about 31 years. Additionally, 28 index wells are equipped with water level recorders, which provide continuous water level data. Of these 28 recorder-equipped wells, 18 have a period of record greater than 14 years. Fifty-two index wells are equipped with pressure transducers which record water levels at a minimum of 4 times per day. These transducer wells all have a very short period of record, approximately less than 5 years.

In areas directly dependent on precipitation for groundwater recharge, water level declines have been significant. This is clearly illustrated by the data collected from the index well near the City of Payson in Climate Division 4. This well has experienced water

level declines of approximately 60 feet between 1988 and 2004. These groundwater level declines are seen elsewhere around the state. In the Phoenix area, within Climate Division 6, water level declines of over 50 feet between 1997 and 2002 have been observed. However, other areas within the same climate division have shown little to no change in the water levels while other areas have shown water level rises for the same period of record. This may be due to artificial recharge projects adding water to the aquifer system and influencing groundwater levels. In Climate Division 2, at an index well located in Fort Valley near Flagstaff, water level declines of over 10 feet in the period of 1991 to 2004 have been observed. Nearby in Chino Valley located in Climate Division 3, an index well has recorded about 40 feet of groundwater decline over the past 20 years. Within Climate Division 7, an index well at Ft. Huachuca has experienced a 15-foot decline over the past 20 years. In general, all of the hydrographs exhibiting declines show that this trend is continuing.

Soil Moisture (Contributed by USDA-NRCS)

There is a serious need for more soil moisture observations in Arizona. Existing surface networks such as monitoring wells, ALERT systems, and SNOTEL sites, can be instrumented with soil moisture sensors to measure soil conditions. The data gathered by these co-located sensors can be used to evaluate the scope and severity of drought by county, watershed, or other spatial scales, and to trigger plans and policies for drought mitigation. Other uses for soil moisture data include engineering applications, risk assessments, prediction of changes in crop, range and woodland productivity, flood analysis, prediction of watershed health, verification and ground-truth of satellite and soil moisture models, and prediction of shifts in wetlands

Ongoing Activities

1. Snowpack Telemetry (SNOTEL) Network - The United States Department of Agriculture Natural Resources Conservation Service (NRCS) operates a network of 15 SNOTEL sites with locations throughout the Verde, Salt, Little Colorado, and Upper Gila River Basins. Three of these sites are instrumented with Hydra Probe soil moisture-soil temperature sensors manufactured by Stevens Vitel. Sensors were installed in 2002-03. SNOTEL information is available online from NRCS at http://www.az.nrcs.usda.gov/.

2. Soil Climate Analysis Network (SCAN) - The SCAN is operated by the NRCS. The network provides hourly observations of air temperature, relative humidity, wind speed, wind direction, solar radiation, precipitation, barometric pressure, soil temperature (at 2, 4, 8, 20, and 40 inch depths), and soil moisture (at 2, 4, 8, 20 and 40 inch depths). One SCAN site is located in the Walnut Gulch watershed near Tombstone, AZ. Records span from 1999 to present. SCAN information is available online from NRCS at http://www.wcc.nrcs.usda.gov/scan/.

3. Remote Automated Weather Stations (RAWS) – Stations report weather observations for land management agencies in Arizona, such as the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS). Most of these stations

monitor data hourly and transmit reports via satellite every 3 hours to a base station. There are 39 BLM stations in Arizona, 9 of these equipped with soil moisture sensors. More information on RAWS can be found online at http://www.fs.fed.us/raws/.

Streamflow (Contributed by USGS)

The U.S. Geological Survey (USGS) operates 196 streamflow-gaging stations in Arizona. The stations are operated to collect stream-discharge data that are used for many purposes, such as flood warning and flood control, the evaluation of climatic extremes (drought and flood), and monitoring streamflow for compacts and decrees. To evaluate drought conditions, 120 stations were initially selected throughout the State (Table ? List of streamflow-gaging stations and period of record – *Chris Smith to follow up in May 2004*). Stations with minimal effect from reservoir regulation and groundwater withdrawals were selected. A few exceptions were included, but for the most part only stations on non-regulated streams were selected. The network of stations will be further refined by comparing the data collected at the stations to data collected at precipitation and temperature stations to identify the stations that best represent drought conditions, thus identifying a network of index stations.

Continuous discharge computed from streamflow-gaging station data will be used to determine monthly mean discharges at each site in the network. Ensuring accuracy of discharge records sufficient for drought monitoring will require monthly site visits by USGS hydrologic technicians to verify the stage-discharge relations used to compute continuous discharge. Monthly mean discharges, which are considered provisional pending an annual review of data, will be made available to the Drought Task Force Monitoring Committee.

Data from the 120 streamflow-gaging stations in the drought-monitoring network have been used to evaluate current and historic drought conditions. The full period of record, which ranges from 3 years to 80 years was used for each station.

Impact assessment and anecdotal data

<u>Agriculture, rangeland, wildlife habitat indicators</u>
The MTC will use subjective monitoring indicators to the extent feasible, such as reports on the conditions of topsoil, vegetation and forage, stock ponds, and wildlife habitat. USDA-NRCS has agreed to provide the MTC with quarterly reports from its ranching conservation districts. A sample quarterly report questionnaire is included in the Attachment to this report. The MTC will seek corresponding input from the Arizona Game & Fish, the University of Arizona Cooperative Extension, and cooperating tribes. Subjective indicators, such as the aforementioned, serve the following functions: to corroborate quantitative indicator information, to provide information from parts of the state for which there are no meteorological or hydrological data stations, to incorporate indicators that integrate hydroclimatic parameters (for example, topsoil and vegetation conditions integrate temperature, precipitation, sunshine, etc.).

<u>Fire and fuel moisture indicators</u>

The MTC will also consult secondary drought monitoring indicators, such as fire danger ratings and fuel moisture assessments. Fire is an important part of the ecology of Southwest forests, and fire danger is intimately associated with multi-season to multi-year variations in precipitation and temperature. Fire danger and fuel moisture assessment data are provided by a variety of state and federal agencies, including the Arizona State Land Department, the Southwest Coordination Center (multi-agency), the US Bureau of Land Management, the USDA-Forest Service, the National Park Service, as well as through the program for Climate, Ecosystems and Fire Applications (Desert Research Institute).

VI. Drought Status and Drought Triggers

Process

During 2003-2004, in response to Governor Napolitano's Executive Order, the MTC investigated the monitoring and assessment sections of drought plans from several western states, and consulted with the National Drought Mitigation Center before deciding on an objective process for triggering drought mitigation and response actions. This method was initially developed for the Georgia Drought Management Plan (2003). The method has been adapted by the MTC to short- and long-term drought categories, in order to trigger drought mitigation and response actions appropriate to the timescales of drought impacts. This process will allow the MTC to closely monitor a relatively small group of parameters for the purpose of triggering drought mitigation and response actions, while monitoring a vast array of spatially specific parameters, to be used to corroborate drought status, less intensively. The MTC developed the drought monitoring and trigger system in conjunction with the GDTF work groups, and performed a preliminary evaluation of the trigger system in conjunction with Arizona resource managers and decision makers. The MTC will continue to evaluate the drought monitoring, indicator, and trigger system described in this report, on at least an annual basis; evaluations will be conducted in workshops with resource managers and users of the MTC drought status reports.

Drought Indicators
Ultimately, drought conditions of any type can be traced to the sole natural moisture input to the hydrologic cycle- precipitation. Likewise, a good measure of the overriding natural removal of water from a hydrologic system is the potential for evaporation, for which the surrogate of air temperature is most often used. Fortunately for drought monitoring, air temperature and precipitation are the two most commonly measured climatic variables. Often these two parameters are combined to produce relative measures of drought. Other indicators that are commonly used to monitor drought conditions include: snowpack, reservoir elevations and current storage, soil moisture, stream flow, groundwater levels, fire and fuel load, and information obtained through observations from local conditions of soil moisture, vegetation and forage, stock ponds, and wildlife habitat.

The MTC selected data from a larger set of potential indicators, mentioned above, because they have the following attributes: continuous and complete monthly records going back to the last multi-decade drought in Arizona (late 1940s-mid 1970s), high quality assurance, and, in the case of streamflow data, little or no human influence. The aforementioned data requirements eliminate data with short, incomplete, or sporadic records from being included

as indicators. However, such data will be consulted to corroborate drought status. The spatial distribution of the data may not be adequate to provide a complete depiction of conditions in all areas of the State. These circumstances will be identified and addressed accordingly as the MTC further develops the resources to do the needed data quality assurance to provide information at a more refined spatial scale.

Triggering Mechanisms and Alert Levels

To implement an objective process for triggering drought mitigation and response actions, the Monitoring Technical Committee developed a science-based approach that uses the correspondence between historical drought impacts and the statistical properties of historical hydrologic and climate data (Steinemann, 2003). This method was initially developed for the Georgia Drought Management Plan (2003). The method has been adapted to a two-drought category system, short- and long-term, to trigger drought mitigation and response actions appropriate to the timescales of drought impacts. This process will allow the Monitoring Technical Committee to closely monitor a relatively small group of drought indicators for the purpose of triggering regional drought mitigation and response actions, while monitoring a vast array of locally relevant indicators less intensively, in order to corroborate the drought status suggested by the drought trigger models. This approach to determining the optimal operational combination of drought indicators to produce effective drought response triggers has also been adapted to account for Arizona's varied topography and to take into account the considerable contribution of snow to Arizona's hydrology.

Analytic Procedures to Calculate Triggers

Drought indicator data measure a variety of phenomena and are often measured on scales (e.g., degrees Fahrenheit, inches of precipitation, cubic feet per second of stream flow, feet below the surface of groundwater) that do not readily correspond to each other for comparative analysis. To provide ease of comparative interpretation, statistical comparability, and temporal and spatial consistency, the indicator data were transformed to percentiles relative to each month. To understand the percentile approach, assume 100 years worth of January temperature data, each value measuring the monthly average January temperature for a particular year. The highest value (hottest temperature) would be in the 1st percentile, whereas the lowest value (coolest temperature) would be in the 100th percentile, and so on for the other 98 values, which would fall between the highest and lowest percentiles. The data were then converted to the corresponding drought trigger levels (see Table 4). For precipitation, standardized precipitation index (SPI) values were calculated. SPI was used, because these data show precipitation in a manner consistent with Monitoring Technical Committee needs for ease of interpretation and statistical comparability. Monthly streamflow data were also converted to percentiles, consistent with the aforementioned approach. Reservoir data, which are influenced by management decisions, will be used only as one of several drought indicators for the Phoenix metropolitan area, combined subjectively (due to artificial, and historically inconsistent, limits imposed on the data by management decisions); reservoir data will also be used for Climate Division 1, on an experimental basis.

Table 4. Overview of Arizona Drought Categories, Impacts, and Trigger Percentiles

Category	Description	Possible Impacts	Indicator Percentiles
0	Normal Conditions		>40.00
1	Abnormally Dry	Measurable reduction in precipitation, stress to seasonal grasses, stock pond storage somewhat reduced	25.01-40.00
2	Moderate Drought	Noticeable reduction in precipitation, some vegetation stress, stock pond storage reduced, reduced streamflows, lower than average reservoir levels	15.01–25.00
3	Severe Drought	Long-term reduction in precipitation, low snowpack, reduction in reservoir levels, vegetation stress affecting trees and shrubs, habitat and pasture degradation	5.01-15.00
4	Extreme Drought	Multi-year precipitation deficits (including snowpack), significant reduction in reservoir levels, measurable reduction in groundwater levels, near-record low streamflows, substantial stress on trees and significant rangeland degradation, diminished wildlife populations	<5.00

For each climate division, the drought indicator data have been divided into groups of short- and long-term indicators. Short-term drought indicators include the 3-, 6-, and 12-month SPI. Long-term drought indicators include 24-, 36-, and 48-month SPI, as well as streamflow at selected gages in each climate division (except Climate Division 5, which has no perennial streams, except the Colorado River, and which is subject to federally-mandated response options based on the status of the Colorado River). Drought status is measured separately for the situation of moving to a higher drought status ("drought in") and for the situation of moving to a lower drought status ("drought out"). In order to ensure smooth transitions between monthly drought status levels, and to bolster the drought plan philosophy of proactive drought planning, indicators for *drought in* must be at a certain or higher level for 2 consecutive months. Drought out indicators must be at a certain or lower level for 4 consecutive months. The indicator trigger levels are then averaged (and rounded up to the nearest whole number) separately for short- and long-term drought status, and for drought in and drought out status. The maximum of drought in or drought out status for each drought category (short- and long-term) is then used to declare the final short- and long-term status.

As significant changes in the status of reservoirs and groundwater occur more slowly than at a monthly time scale, the Monitoring Technical Committee will release an *annual* report

on the drought status of the two major metropolitan areas, based on reservoir levels, annual groundwater index well data, and short-term precipitation data, as they pertain to each metro area. For each climate division, annual groundwater index well data, and seasonally available snow water equivalent and SWSI data, as well as a host of other drought impact data will be consulted before finalizing drought trigger status.

Combinations of the indicator data described above have been evaluated for their faithful representation of past drought conditions. The evaluations use actual data, to generate the triggering sequences that would have occurred historically. These sequences were then compared to retrospective assessments of drought according to Arizona resource managers and decision makers. Sets of triggers were selected for the short- and long-term drought categories. The Monitoring Technical Committee will evaluate the performance of the drought trigger system at least annually, in order to assure that the indicator data and combinations of indicators used to trigger drought status are consistent with observed drought impacts. (Note: post-drought triggers might need to be reassessed in the future.)

VII. Drought Trigger and Declaration Process

The Monitoring Technical Committee will routinely monitor and evaluate the drought indicators that are supplied by its constituent agencies. These indicators reflect the state of the hydrologic system. The indicators for each of Arizona's seven climate divisions are described in Appendix V of the Arizona Drought Preparedness Plan. In keeping with the philosophy outlined earlier in this plan, the Governor's Drought Task Force advocates proactive responses to potential drought. Therefore, as mentioned above, drought triggers going into drought are relatively more sensitive to impending drought (but avoiding drought false alarms), and triggers going out of drought are relatively conservative (but avoiding excessive restrictions), to assure that mitigation in response actions are not withdrawn prematurely.

Operational drought triggers are defined in terms of combinations of various observed hydrologic and climatic measurements (e.g., precipitation, stream flow), and the threshold levels associated with those variables (Table 4). This procedure produces an objective measure for triggering specific drought mitigation and response actions. At the same time, the Arizona Drought Preparedness Plan must retain flexibility to address situations where strict adherence to or reliance on a specific threshold would be inappropriate. The Arizona Drought preparedness Plan must also ensure that this discretionary latitude does not weaken the proactive approach by forestalling timely responses. The Monitoring Technical Committee will use a two-step approach to evaluating and recommending a change in status of the drought conditions, as follows: a preliminary trigger, based on the availability of high-quality, continuous, monthly-resolution, long-term data, will be used as the first indicator of drought for a specified climate division; an intensive evaluation of additional drought indicator data for sub-regions within that climate division will be used to confirm the trigger and thus trigger a notification of a change in the drought status.

Preliminary trigger:
Going into drought. For each of the drought categories (short- and long-term), the individual indicators in a climate division must reach or pass a certain prescribed threshold for two consecutive months. The average of short-term indicators (rounded up to the

nearest whole number) is then taken each month; similarly the rounded-up whole number average of long-term indicators is then taken each month.

Coming out of drought. For each of the drought categories (short- and long-term), the individual indicators in a climate division must reach or be lower than a certain prescribed threshold for four consecutive months. The average of short-term indicators (rounded up to the nearest whole number) is then taken each month; similarly the rounded-up whole number average of long-term indicators is then taken each month.

Drought status. The maximum of drought in and drought out values for short-term drought is used as the final preliminary trigger for short-term drought status, and the maximum of drought in and drought out values for long-term drought is used as the final preliminary trigger for long-term drought status.

Evaluation: Once a drought status trigger has been "tripped," the Monitoring Technical Committee will convene and use additional drought indicators and local-scale and high spatial resolution data in order to determine the geographic extent of drought alert within the particular climate division. The Monitoring Technical Committee will also incorporate subjective monitoring measures, such as quarterly ranching conservation district status reports provided by US Department of Agriculture – Natural Resources Conservation Service, into evaluating the extent of drought and the need for drought declaration.

As explained above, the Monitoring Technical Committee will evaluate the performance of the drought trigger system at least annually, in order to assure that the indicator data and combinations of indicators used to trigger drought status, and ancillary data used to corroborate drought status, are consistent with observed and impending drought impacts. Moreover, MTC members will be conducting a careful sensitivity analysis of the trigger system during 2004-2005.

VIII. Integration of Climate and Weather Information

The MTC is faced with considerable technical and conceptual challenges in monitoring drought in Arizona, including the following: (1) accounting for extremely diverse topography and dramatic elevation changes within relatively short distances; (2) urban areas that receive supplemental water supplies from out-of-state sources dependent on short- and long-term hydroclimatic variations sometimes unrelated to those within Arizona – requiring the MTC to monitor climate and water supply conditions outside of state boundaries (3) major spatial gaps in climate and snow monitoring networks, especially at higher elevations, and spatial and temporal gaps in groundwater and soil moisture monitoring networks, (4) a need to take into account systems designed to buffer water supplies (i.e., water banking), (5) the question of how to portray the multiple scales of drought that might affect well buffered urban/suburban core areas very differently than nearby outlying areas.

IX. Responsibilities and Communication

Meetings and Reports

The MTC will meet monthly throughout the year, and will coordinate with Arizona Flood Warning, in order to produce a seamless assessment of hydroclimatic hazard for Arizona. The MTC will provide a summary of drought conditions, and any recommendations it may have, to the GDTF at the conclusion of its meetings. The MTC will provide public access to the data it monitors, and its summaries and recommendations, via the World Wide Web. The data on the Web will updated at least as frequently as the Committee meets. Data from various networks may be updated more frequently at the discretion of the owner of the data network (probably ADWR).

Portraying drought monitoring information in a way that takes into consideration considerable disparities in Arizona urban-rural drought vulnerabilities/drought status, will require state-of-the-art knowledge transfer and creative visualization. The MTC, in coordination with member agencies and with plans for a National Integrated Drought Information System (WGA, 2004), will assess Arizona drought monitor usability, in order to guarantee that decision makers can understand and make the best use of drought monitoring products and science.

X. References

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Worksheet for Use in Determining Local Drought Conditions

Work Area/Office Location: _____ Date: _____

To be determined locally. Answer if applicable:

1. Storage remaining in stock ponds/earthen tanks in your work area (livestock water)
   -- % of capacity (inclusive of stock ponds in your work area):

2. Was water hauling necessary?
   -- for what purpose?

3. Groundwater
   -- are existing wells in your work being drilled deeper as the result of drought (for livestock water
   or for irrigation)?
   -- are there new wells being drilled, and for what purpose?

4. Direct stream diversions
   -- will irrigators have adequate water supplies this season (if pre-planting)?
   -- did irrigators have adequate water supplies this season (if post-harvest)?
   -- % of normal water deliveries, if known:

5. In your work area, were farm and ranch changes made because of inadequate water supplies?
   -- % livestock numbers reduced:
   -- were crop changes made:
   -- was crop acreage adjusted due to water supply:

6. Rangeland impacts (ocular est.)
   -- % forage production of key species compared to normal years:
   -- other impacts:

7. Natural spring production in your work area?
   -- above normal
   -- normal:

-- below normal:

8. How would you rate soil moisture in your work area?

Top and Sub-Soil Moisture: (with top-soil defined as the top 6 inches):

Very Short - Soil moisture supplies are significantly less than what is required for normal plant development. Growth has been stopped or nearly so and plants are showing visible signs of moisture stress. Under these conditions, plants will quickly suffer irreparable damage.

Short - Soil dry. Seed germination and/or normal crop growth and development would be curtailed.

Adequate - Soil moist. Seed germination and/or crop growth and development would be normal or unhindered.

Surplus - Soil wet. Fields may be muddy and will generally be unable to absorb additional moisture. Young developing crops may be yellowing from excess moisture.

Appendix VII
WORKGROUP REPORTS – COMMERCE, RECREATION, AND TOURISM

Arizona Drought Preparedness Plan
Impact and Drought Assessment
Commerce, Recreation & Tourism Workgroup Report
June 1, 2004

1. Introduction/Overview/Purpose

This chapter addresses the Commerce, Recreation and Tourism sectors of Arizona's economy in the context of past drought impacts, regional vulnerabilities, monitoring needs, mitigation and adaptation options, and emergency response options. The key drought related events that cause impacts in these sectors include:

- Forest closures that affect park/forest visitation and associated activities such as camping, hiking, hunting, and fishing;
- Wildfires and associated impacts on forest industries and environmental quality;
- Low surface water flows and reservoir levels that limit water-based recreation such as boating and rafting;
- Reduced snowpack affecting the length of the ski season and number of skiers; and,
- Potable water supply limitations that affect the service industry and rural communities.

Any reduction in tourism and recreation activity is likely to affect the food service and hospitality industries, as well as the tourism and recreation services and outfitters that are prevalent in rural areas. All of these impacts likely have resulted in job losses as well as a reduction in revenues in the recent drought, though there is little documentation of these outcomes in Arizona. (For documentation of similar impacts in Colorado, see the "2003 Drought Impact and Mitigation Report" compiled by the Colorado Dept. of Natural Resources) [1].

Information to develop this chapter was gleaned from a number of sources. The Commerce, Recreation and Tourism (CRT) workgroup was formed in November of 2003 (see Attachment 1). The CRT Workgroup developed a survey in attempt to capture information regarding the impacts of drought on commerce, recreation and tourism.
The purpose of the survey was three fold.

1. Identify primary and secondary negative impacts of drought on local or regional recreation and tourism,
2. Identify sources of information, published and electronic, on research and efforts of others regarding the analysis of drought on recreation and tourism,
3. Identify potential participants that might contribute to the work of Drought Task Force.

The survey instrument and generic cover letter are attached as Attachment 2. The survey was distributed in January 2004 electronically through email by the individual members of the CRT Workgroup to their contacts and associates within each member's area of expertise or study. The survey was emailed to approximately 100 contacts within

recreation, tourism, chamber of commerce, natural resource management and business development communities throughout Arizona.

The results of the survey are attached as Attachment 3, Summary of Results - Commerce, Recreation and Tourism Survey, January 2004.

Several noteworthy themes emerged. First, respondents were extremely concerned about the negative publicity associated with drought impacts, and interested in finding new ways to communicate recreation opportunities that continue to be available during periods drought. They are particularly interested in correcting misperceptions about the severity of drought conditions. Other respondents were concerned about the aesthetic impacts of drought, particularly on desert vegetation and landscaping and the effects of the recent infestation of bark beetles in ponderosa pine forests. Other concerns included wildlife impacts, air quality, the urban heat island effect, and particularly the significant impact on the ranching economy, including herd loss.

2. Tourism Sector – Background and Past Impacts

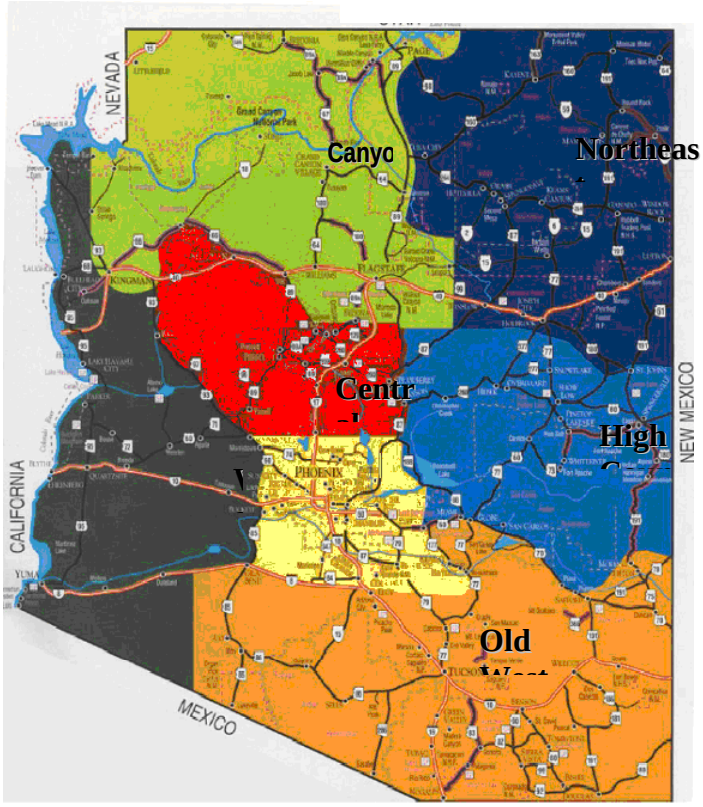
The economic impact of tourism in Arizona, though very significant, is difficult to measure. Unlike most industries, which are composed of a number of firms engaged in the same primary activity, tourism is a diverse collection of firms engaged in many different activities.

Nonetheless, the 26.9 million tourists to Arizona in 2002 directly spent approximately $16 billion while visiting the Grand Canyon State. Tourists to Arizona were also directly and indirectly responsible for over 450,000 jobs statewide in foodservice, transportation, lodging, entertainment/recreation, general trade/retail and travel planning. Salaries and wages, both directly and indirectly related to tourism in Arizona totaled nearly $12 billion. In addition, Arizona's tourism sector generated nearly $1 billion in tax revenue in 2002. [2]

Even though the impact of drought on Arizona's commerce, recreation and tourism industries is difficult to observe directly, inferences of the impacts of drought can be made when characteristics of Arizona's tourism sector are viewed in context.

For economic analysis purposes the State of Arizona is divided into seven distinct tourist regions. Tourist profiles and statistics are compiled by the Arizona Department of Tourism by region. The regions are delineated on the map below.

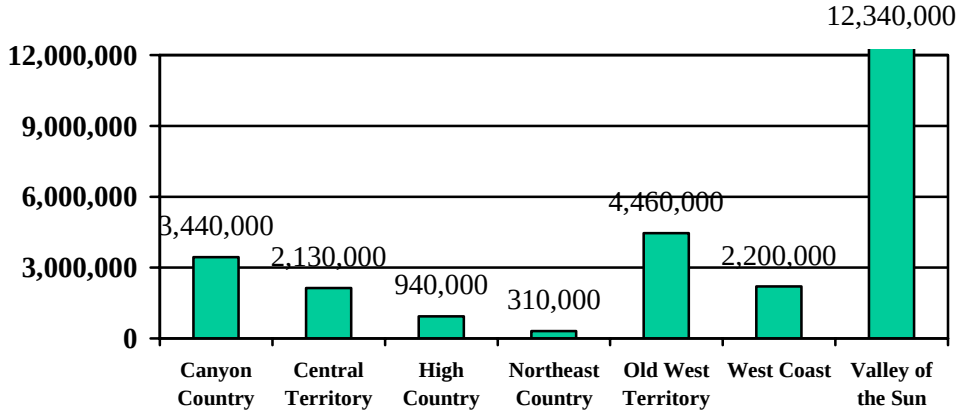
Tourism Regions in Arizona



- Canyon Region
  Sedona, Flagstaff, Grand Canyon
- Central Territory Region
  Prescott, Verde Valley, Wickenburg
- High Country Region
  Heber, Springerville, Mogollon Rim, White Mountains
- Northeast Country Region
  Navajo & Hopi Reservations, Holbrook
- Old West Country Region
  Tucson, Bisbee, Wilcox, Nogales
- West Coast Region
  Yuma, Parker, Lake Havasu City, Colorado River
- Valley of the Sun Region
  Metropolitan Phoenix, Casa Grande

The following chart illustrates the number of tourists that visited Arizona in 2002 by region. Although over 62% of the tourists to Arizona visited the two metropolitan regions, the Valley of the Sun and the Old West Regions, over 10 million tourists were visitors to rural Arizona. Northern Arizona, including the Canyon Country, Central Territory, High Country and Northeast Country Regions, was the destination for nearly 7 million tourists in 2002.

Regional Breakdown of Visitors to AZ in 2002



The 2002 tourist year for Arizona was a difficult one for reasons beyond the drought. In particular, there was a significant nationwide reduction in travel following the September 11, 2001 terrorist events. Between 2001 and 2002 total domestic overnight visitors to Arizona (excluding international visitors) declined from 27.1 million visitors to 26.9 million visitors. Over 11,000 tourist-related jobs were lost during the same period. [3]

All of Arizona's National Forests were subject to some level of use restrictions or total forest closures during 2002 because of the threat of major wildfires due to continuing drought conditions. The Rodeo-Chediski fire along the Mogollon Rim, which burned nearly a half million acres in Northern Arizona, received prominent national news coverage throughout much of the summer of 2002.

"This is an extraordinary year that requires extraordinary measures." said Mike King, Forest Supervisor of the 1.25 million acre Prescott National Forest, when he announced the closure of the forest in May 2002, approximately 10 days after the 1,000 acre Indian Fire just outside Prescott. Violation of the closure was punishable by a fine of not more than $5000 or imprisonment for not more than 6 months, or both. [4]

Forest closures result when entry to National Forests, Bureau of Land Management lands, Arizona State Trust lands or other public lands is barred, except for area property owners and holders of special use permits. [5] Conditions for forest re-opening include: significant moisture especially in critical areas, availability of firefighting resources, anticipated weather trends and wood-fuel moisture, number of daily fire starts, anticipated number of forest visitors and socio-political considerations. [6]

Business and merchants in Sedona and other tourism-dependent cities across parts of the West say that fire fears and the reduction in tourist visitors in 2002 almost literally burned holes in their pockets. Sedona, whose summer attractions depend on access to the outdoors, saw not only the shutdown of the 1.8 million acre Coconino National Forest, but also of Arizona's most popular state park, Slide Rock State Park on Oak Creek. "Thousands of potential out-of-state visitors are bypassing Arizona altogether" said tourism officials at the time, a product of the national media attention paid to the Rodeo-Chediski fire. In 2002, Arizona Department of Tourism spent $50,000 on a late summer in-state advertising campaign to persuade Arizonans to visit Sedona and the rest of northern Arizona.

Visitations to national parks in Arizona declined by 823,000 visitors or a decrease of 7% from 2001 to 2002. There were 73,000 fewer visitors to the Grand Canyon National Park alone. [2]

Similarly, visitations to Arizona state parks declined by 259,000 visitors or a decrease of 10% between 2001 and 2002. Visitations to Slide Rock State Park on Oak Creek, for example, which was closed for a portion of 2002 due to drought-related concerns, experienced a decline of 105,000 visitors. [2] The continuing drought through 2003 has especially affected all of Arizona's parks that have lakes. Water levels at Alamo Lake,

Lyman Lake and Ellen Bilbrey Lake State Parks were so low that those visitors who did stopover were unable to launch their boats. [7]

The drought was directly related to two major threats that damaged Williams' economy in 2002, which depends almost entirely on tourism. Its five reservoirs were at 6% capacity at the end of 2002; in fact two were completely dry. Forest fires in the summer of 2002 charred large expanses of nearby dry forest, and forest closures scared many tourists away.

The continuing drought has exacerbated the risk of catastrophic wildfire in about two-thirds of the forested land in the Southwest. Severely stressed trees in overly dense forests make them even more susceptible to attack by insects and disease. Between 2001 and 2002 the areas affected by bark beetles in Arizona have increased by sevenfold, and there is a 20-fold increase over the 1998-2001 average. Hundreds of thousands of acres of dead pinion and ponderosa pine and other tree and shrub species continue to contribute to a "fuel" situation that is manifesting itself in more fires; fires that are uncharacteristically large, intense, damaging, and threatening to communities in the urban-wild land interface. [8]

Tourism in Flagstaff accounts for more than 20% of all business. Hotels and restaurants alone employ 8 percent of all Coconino County workers. Tourism-related business accounts for 12 percent of income within the county, four times the national average. Because tourists account for about 50 percent of the city's sales tax revenues, and two-thirds of Flagstaff's Bed, Board and Booze tax, any decline in tourism significantly and directly affects the town. [9]

In an effort to combat the impacts of continuing drought, the Arizona Office of Tourism announced in January 2004 its intention to boost tribal and state visitations by hiring a full-time Native American tourism development manager to promote tourism on Indian lands and to form a tribal advisory council. [10]

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11.,Arizona Daily Sun, August 24, 1997, *Tourism-Direct Spending Tops $200 Million.*
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3. Arizona Recreation and Tourist Sites by Climate Division

The State of Arizona is divided into seven climate divisions. Unfortunately, Arizona's seven climate divisions are not the same areas as delineated in Arizona's Tourism Regions. The climate divisions are based on U.S. Department of Agriculture (USDA) crop reporting districts, and bear the same names and areas as the USDA districts. Climatic data is frequently collected, aggregated and displayed by climate division.

Climate Division 1, the Northwest Division, includes Mohave County and the communities of Kingman and Lake Havasu City. Many of the recreational sites and visitor destinations are water related and tied to the Colorado River in this region of the State.

Climate Divisions in Arizona

Climate Division 2, the Northeast Division, includes Coconino, Navajo and Apache Counties and the communities of Flagstaff, Sedona, and Winslow. CD 2 contains the areas of highest elevation and 3 of the State's four snow ski areas are located here. Climate District 2 also contains 4.2 mil acres of National Forest, the highest amount of all the divisions.

Climate Division 3, the North Central Division, includes Yavapai County, and the communities of Prescott, Prescott Valley and the Verde Valley communities of Cottonwood, Camp Verde and Clarkdale. CD 3 is likely the fastest growing rural area of Arizona.

Climate Division 4, the East Central Division, includes Gila County and the communities of Globe, Miami and Payson. The northern portion of CD 4 includes the recreation areas of the Mogollon Rim while conventional large open-pit copper mining predominates the southern region of CD 4.

Climate Division 5, the Southwest Division, includes the counties of Yuma and La Paz, and the communities of Parker, Yuma and San Luis. Many of the recreational sites of this low desert region are also tied to water recreation along the Colorado River.

Climate Division 6, the South Central Division, includes Maricopa and Pinal Counties and the communities of metropolitan Phoenix, Casa Grande, Florence and Superior. CD 6 contains the highest concentration of population in the State located in large urban communities that are typically insulated from the impacts of drought due to significant infrastructure tied to the Central Arizona Project, regional surface water reservoirs in addition to deep groundwater wells.

Climate Division 7, the Southeast Division, includes the counties of Pima, Santa Cruz, Cochise, Graham and Greenlee. Communities in CD 7 include Tucson, Green Valley, Nogales, Sierra Vista, Wilcox and Safford. In addition to the second highest

concentration of population of Arizona's divisions, CD7 also has the second highest number of National Forest acres at 2.4 mil acres.

There are significant recreational sites and tourist attractions within each climate division. The flowing tables identify the recreational and tourist sites by climate division. The recreational and visitor attraction data is derived from the *Recreational Map of Arizona*, © 1997, GTR Mapping. Population data is from the U.S. Census Bureau, *Census 2000 Redistricting Data*. Land Ownership information is from *2002 Arizona Agricultural Statistics*. While the tables are as complete as possible, they do not include, for example, specific camp and picnic grounds within national forests, or specific sites within tribal recreational areas or reservations.

Table 1. Arizona Recreation and Tourist Sites in Climate Division 1
Northwest Division

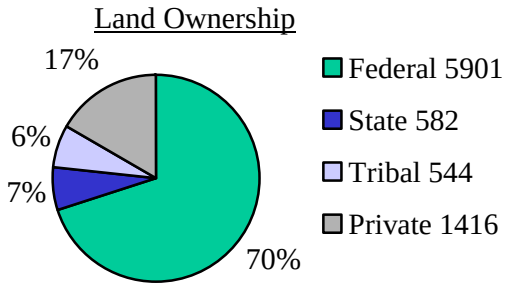
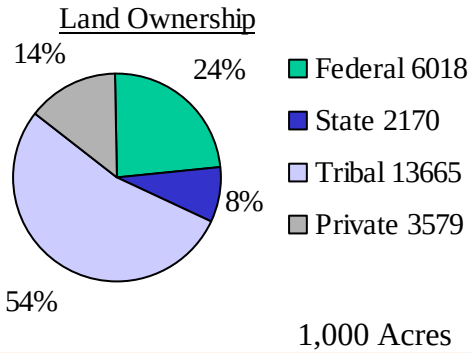
	 1,000 Acres
County	Mohave County 8,443,000 Acres
Communities	Kingman, Lake Havasu City
2000 Population	155,032 11.6 persons per square mile
National Parks	Grand Canyon National Park (portion)
National Monuments	Pipe Springs National Monument
National Recreation Areas	Lake Mead National Recreation Area
National Wildlife Refuges	Havasu National Wildlife Refuge
Native American Reservations	Fort Mohave Reservation, Hualapai Reservation, Kaibab Reservation
State Parks	Lake Havasu State Park at Parker Dam, Cattail Cove State Park
Visitor Attractions	Chloride, Davis Dam & Power Plant, Dolan Springs, Goldroad, Historic Route 66, Hoover Dam, Hualapai Valley Joshua Trees, Mohave Museum of History & Arts, London Bridge/English Village, Lake Mohave, Mineral Park, Oatman, White Hills.
Wilderness Areas	Paiute Wilderness Area, Beaver Dam Mountains Wilderness Area, Cottonwood Point Wilderness Area, Grand Wash Cliffs Wilderness Area, Mount Logan Wilderness Area, Mount Trumbull Wilderness Area, Mount Wilson Wilderness Area, Mount Tipton Wilderness Area, Mount Nutt Wilderness Area, Warm Springs Wilderness Area, Wabayuma Peak Wilderness Area, Aubrey Peak Wilderness Area, Arrastra Mountain Wilderness Area, Swansea Wilderness Area.

Table 2. Arizona Recreation and Tourist Sites in Climate Division 2
Northeast Division

	
County	Coconino, Navajo, Apache Counties 25,432,000 Acres
Communities	Flagstaff, Page, Sedona, Seligman, Williams, Holbrook, Snowflake, Taylor, Winslow, Eager, Springerville, St. Johns
2000 Population	283,222 7.1 persons per square mile
National Parks	Grand Canyon National Park (portion), Petrified Forest National Park
National Forests	Sitgreaves National Forest, Coconino National Forest, Kaibab National Forest, Apache National Forest 4,250,000 Acres
National Monuments	Sunset Crater National Monument, Walnut Canyon National Monument, Wupatki National Monument, Rainbow Bridge National Monument, Navajo National Monument, Canyon de Chelly National Monument
National Recreation Areas	Glen Canyon Recreation Area
Native American Reservations	Hualapai, Kaibab, Fort Apache, Hopi, Navajo, Zuni
Ski Areas	Arizona Snowbowl, Williams, Sunrise
State Parks	Slide Rock State Park, Riordan Mansion State Park, Lyman Lake State Park, Fool Hollow Lake, Homolovi Ruins State Park
Visitor Attractions	COCONINO COUNTY -Battle of Big Dry Wash, Arboretum at Flagstaff, Arizona Historical Society, Pioneer Museum, Coconino Center for the Arts, Elden Pueblo, Lowell Observatory, Museum of Northern Arizona, Northern Arizona University, Tusayan Ruins & Museum, Yavapai Museum, Supai Canyon on the Havasupai Reservation, House Rock Valley, Lees Ferry, Meteor Crater, Mogollon Rim, Mormon Lake, Oak Creek Canyon,

	Dinebekah Museum, Glen Canyon Dam / Carl Hayden Visitor Center, John Wesley Powell Memorial Museum, Lake Powell, Grand Canyon, Grand Canyon Caverns, Grand Canyon Village, North Rim Scenic Overlooks (Bright Angel Point, Cape Royal, Point Imperial, Vista Encantadora, Walhalla Overlook), Phantom Ranch, South Rim Scenic Overlooks (Desert View, Grandview Point, Hermits Rest, Hopi Point, Lipan Point, Moran Point, Pima Point, Yaki Point, Yavapai Point), Tusayan, San Francisco Peaks, Chapel of the Holy Cross, Red Rock Crossing, Cathedral Rock Sedona Arts Center, Harvey House –Roundhouse, Historic Route 66, Bill Williams Monument, Deer Farm, Grand Canyon Railway APACHE COUNTY-Casa Malpais, Coronado Trail, Little House Museum, Hubbell Trading Post National Historic Site, Painted Desert, Raven Site Ruins, Madonna of the Trail Museum, White Mountains NAVAJO COUNTY-Fort Apache, Old County Courthouse and Museum, Little Painted Desert, Flake and Smith Memorial Pioneer Homes, Sunset Crossing.
Wilderness Areas	Strawberry Crater Wilderness Area, Kanab Creek Wilderness Area, Paria Canyon Vermillion Cliffs Wilderness Area, Saddle Mountain Wilderness Area, Kendrick Mountain Wilderness Area, Kachina Peaks Wilderness Area, Sycamore Canyon Wilderness Area, West Clear Creek Wilderness Area

Table 3. Arizona Recreation and Tourist Sites in Climate Division 3
North Central Division

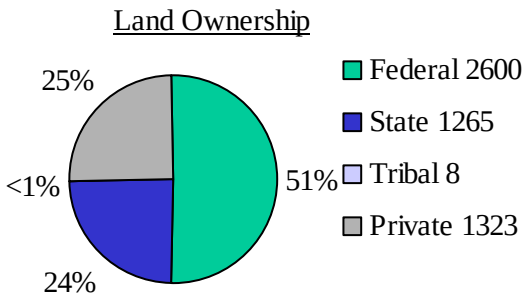
	 1,000 Acres
County	Yavapai County 5,196,000 Acres
Communities	Clarkdale, Cottonwood, Camp Verde, Jerome, Prescott, Yarnell
2000 Population	167,517 20.6 persons per square mile
National Forests	Prescott National Forest 1,969,000 Acres
National Monuments	Montezuma Castle National Monument, Tuzigoot National Monument
National Recreation Areas	General Crook National Recreation Trail
Native American Reservations	Yavapai Prescott, Yavapai Apache
State Parks	Dead Horse Ranch State Park, Ft. Verde State Historic Park, Jerome State Historic Park, Red Rock State Park.
Visitor Attractions	Arcosanti, Arizona Central Railroad, granite Basin, Granite Dells, Douglas Mining Museum, Historic Old Jerome, Jerome Historical Society Museum, Lake Pleasant, Lynx Lake, Montezuma Well, Ft. Whipple, Phippen Museum of Western Art, Prescott Animal Park, Prescott Fine Arts Association, Sharlot Hall Museum, Verde Valley, Stanton, Tiger, Walker, Shrine of St. Joseph.
Wilderness Areas	Juniper Mesa Wilderness Area, Hassayampa River Canyon Wilderness Area, Wet Beaver Wilderness Area, Fossil Springs Wilderness Area, Pine Mountain Wilderness Area, Cedar Bench Wilderness Area, Castle Creek Wilderness Area, Upper Burro Creek Wilderness Area, Bradshaw Mountains Wilderness Area

Table 4. Arizona Recreation and Tourist Sites in Climate Division 4
East Central Division

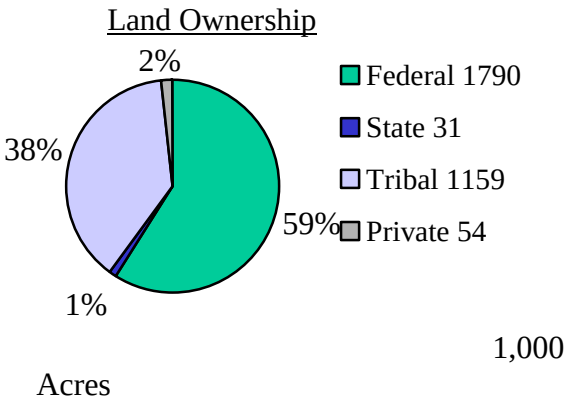
	
County	Gila County 3,051,000 Acres
Communities	Globe, Miami, Claypool, Payson, Strawberry,
2000 Population	51,335 10.8 persons per square mile
National Forests	Tonto National Forest 1,705,000 Acres
National Monuments	Tonto National Monument
Native American Reservations	Fort Apache Reservation, San Carlos Reservation
State Parks	Tonto Natural Bridge State Park
Visitor Attractions	Black Mesa Ruins, Bloody Tanks, Camp Reno, Cherry Creek Cliff Dwellings, Besh-Ba-Gowah Archeological Park, Cobre Valley Center For The Arts, Downtown Globe Historic District, Gila County Historical Museum, Old Dominion Mine, Old Gila County Jail, McMillan, Mogollon Rim, Museum of the Forest, Payson Zoo, Swiss Village, Pine, Roosevelt Lake / Roosevelt Dam, Salt River Canyon, Coolidge Dam, Sierra Ancha Experimental Forest, Strawberry, Oldest Standing Schoolhouse in Arizona, Tonto Creek Fish Hatchery, Zane Grey Cabin.
Wilderness Areas	Hellsgate Wilderness Area, Mazatzal Wilderness Area, Salome Wilderness Area, Salt River Canyon Wilderness Area, Sierra Ancha Wilderness Area, Needle's Eye Wilderness Area.

Table 5. Arizona Recreation and Tourist Sites in Climate Division 5 Southwest Division

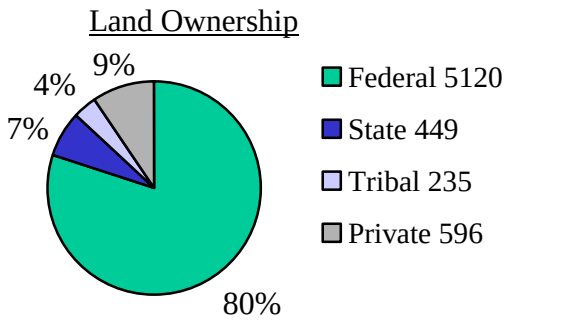
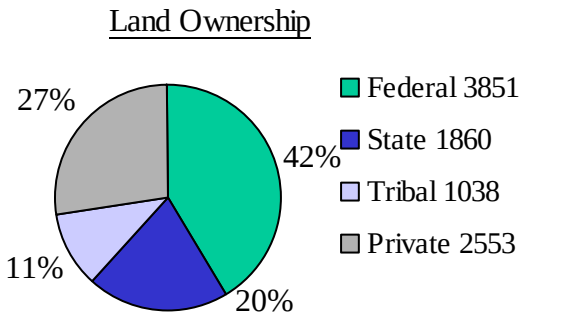
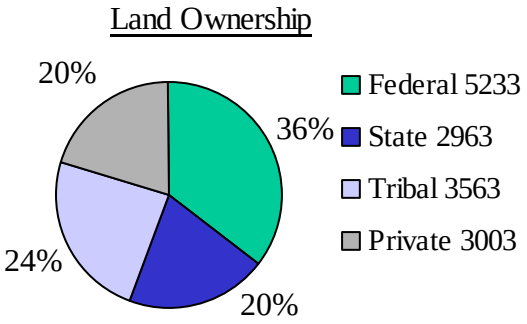
	 1,000 Acres
County	La Paz and Yuma Counties 6,400,000 Acres
Communities	Parker, Ehrenberg, Quartzite, Yuma, Welton, San Luis
2000 Population	179,741 17.9 persons per square mile
National Wildlife Refuges	Cibola National Wildlife Refuge, Kofa National Wildlife Refuge, Havasu National Wildlife Refuge, Cabeza Prieta National Wildlife Refuge, Imperial National Wildlife Refuge
Native American Reservations	Colorado River Reservation, Cocopah Reservation, Quechan Reservation
State Parks	Alamo Lake State Park, Buckskin Mountain State Park, River Island State Park, Yuma Crossing-Quartermaster Depot State Park, Yuma Territorial Prison State Park
Visitor Attractions	LA PAZ COUNTY -House Scenic Route, Colorado River, Ehrenberg, Harrisburg, Colorado Indian Tribes Museum, Parker Dam, Quartzsite, Gravesite of Hadji Ali Tyson Wells Museum, Picture Rock YUMA COUNTY-Castle Dome Mountains, Colorado River, Imperial Dam, Kofa, Laguna Dam, Martinez Lake, McElhaney Cattle Company Museum, McPhaul Bridge, Mittry Lake, Morelos Dam, Palm Canyon, Century House Museum, Fort Yuma, Quechan Indian Museum, St. Thomas Mission, Southern Pacific Steam Locomotive, Steamboat Landing, Yuma Art Center, Yuma Valley Railroad
Wilderness Areas	Gibraltar Mountain Wilderness Area, Rawhide Mountain Wilderness Area, East Cactus Mountain Wilderness Area, Harcuvar Wilderness Area, New Water Mtn Wilderness Area, Eagletail Mtn Wilderness Area, Trigo Mountain Wilderness Area, Imperial Refuge Area, Muggins Mtn Wilderness Area.

Table 6. Arizona Recreation and Tourist Sites in Climate Division 6
South Central Division

	
County	Maricopa and Pinal Counties 9,302,000 Acres
Communities	Gila Bend, Phoenix, Scottsdale, Mesa, Tempe, Glendale, Peoria, Buckeye, Casa Grande, Coolidge, Florence, Superior, Kearny, Mammoth, San Manuel
2000 Population	3,251,876 223.1 persons per square mile
National Forests	Tonto National Forest 881,000 Acres
National Monuments	Casa Grande Ruins National Monument
Native American Reservations	Fort McDowell Reservation, Gila River Reservation, Salt River Reservation, Papago Reservation, Maricopa Ak-Chin Reservation, Papago Reservation (Tohono O'odham Tribe)
State Parks	Boyce Thompson State Park, Lost Dutchman State Park, McFarland St. Historical Park, Picacho Peak State Park
Visitor Attractions	MARICOPA COUNTY-Agua Caliente Hot Springs, Apache Lake, Bartlett Reservoir, Canyon Lake, Gatlin Archeological Area, Gila Bend Museum & Information Center, Hassayampa River Preserve, Horseshoe Lake, Lake Pleasant, Oatman Massacre, Painted Rocks Dam, Adventure Sports, Aeronautical Adventure, Arizona Hall of Fame Museum, Arizona Historical Society Museum, Arizona Museum, Arizona Museum for Youth, Arizona Museum of Science & Technology, Arizona Ski Springs, Arizona St. Capitol Museum, Arizona State University, Big Surf, Bob Parks Gallery, Biosphere, Buckeye Valley Museum, Buckhorn Wildlife Museum, Cave Creek Museum, Champlin Fighter Museum, Crismon Farm & Heritage Museum, Desert Botanical Gardens, Gilbert Historical Museum,

	Hackett House, Hall of Flame, Heritage Square / Rosson House Museum, McCormick Railroad Park, Mesa Southwest Museum, Mormon Temple Visitor Center, Glendale Municipal Art Gallery, Mystery Castle, Niels Petersen House, Out of Africa Wildlife Park, Papago Park, Phoenix Art Museum, Phoenix - Valley of the Sun Visitor & Convention Bureau, Phoenix Zoo, Pueblo Grande Museum & Cultural Park, Rawhide 1880's Western Town, Rockin R Ranch, Sahuaro Ranch Park Historical Area, Salt River Project History Center, Scottsdale Center for the Arts, Taliesin West, Wright Foundation & Architectural School, Tempe Arts Center, Tempe Historical Museum, The Fleischer Museum, Tovrea Castle, Van's Pretty Rocks, Wildlife World Zoo, Saguaro Lake, Hoogam Ki Museum, Vulture Mine and Vulture City, Desert Caballeros Museum, Massacre Monument, Wickenburg Memorial, Wishing Well, Hassayampa River. PINAL COUNTY-Agate Fields, Apache Leap, Apache Tears Caves, Apache Trail, Aravaipa Canyon, Barony of Arizola, Biosphere II, Borree Corner, Box Canyon, Casa Grande Historical Museum, Cochran, Blackwater Trading Post & Museum, Coolidge Dam, San Carlos Lake, Elephant Trees, Florence Historic District, Pinal County Courthouse, Pinal County Historical Museum, Gila River Arts & Crafts Center, Sacaton, Goldfield, Superstition Mountain Museum, Kelvin, Superstition Mountains, Hayden Open Pit Copper Mine, Maricopa Historic Railroad Depot, Mine With The Iron Door, Olberg, Acadia Ranch Museum, Oracle Center for Environmental Education, Picket Post House Museum, Poston Butte, Riverside, Magma Copper Company, John Wayne’s Red River Land Company, ASARCO, Robert T. Jones House, Tom Mix Monument
Wilderness Areas	Big Horn Mountain Wilderness Area, Hummingbird Springs Wilderness Area, Signal Mountain Wilderness Area, Woolsey Peak Wilderness Area, South Maricopa Mountains Wilderness Area, North Maricopa Mountains Wilderness Area, Table Top Wilderness Area, Sierra Estrella West Wilderness Area, Four Peaks Wilderness Area, Superstition Wilderness Area, White Canyon Wilderness Area, Aravaipa Canyon Wilderness Area

Table 7. Arizona Recreation and Tourist Sites in Climate Division 7 Southeast Division

	 1,000 Acres
County	Pima, Santa Cruz, Cochise, Graham & Greenlee Counties 14,762,000 Acres
Communities	Tucson, Green Valley, Nogales, Sierra Vista, Douglas, Wilcox, Safford, Clifton
2000 Population	1,041,918 45.4 persons per square mile
National Parks	Saguaro National Park
National Forests	Coronado National Forest, Apache National Forest 2,445,000 Acres
National Monuments	Organ Pipe Cactus National Monument, Chiricahua National Monument
National Wildlife Refuges	Buenos Aires National Wildlife Refuge, Cabeza Prieta National Wildlife Refuge, San Bernardino National Wildlife Reserve
Native American Reservations	Papago Reservation (Tohono O'odham Tribe), Pascua Yaqui Reservation, San Xavier Reservation, San Carlos Reservation
Ski Areas	Mount Lemmon
State Parks	Catalina State Park, Patagonia Lake State Park, Tubac Presidio State Historical Park, Tombstone Historical State Park, Kartchner Caverns State Park, Roper Lake State Park
Visitor Attractions	PIMA COUNTY-Ajo Historical Society Museum, Ajo Mine, Copper Wire Epitaph, Greenway Mansion, Greenway Memorial, Catalina Highway, Mount Lemmon, Colossal Cave, Titan Missile Museum, Kitt Peak National Observatory, Madera Canyon, The Breakers Waterpark, Sabino Canyon, San Xavier Del Bac Mission, Picture Rocks, Arizona Historical Society Museum, Arizona State Museum, Arizona- Sonora

	Desert Museum, Tucson Mountain Park, B & B Cactus Farm, Flandrau Science Center & Planetarium, Fort Lowell Museum, International Wildlife Museum, Old Tucson & Old Tucson Studios, Pima Air Museum, Reid Park Zoo, Sosa-Carillo-Fremont House, Tohono Chul Park, Tucson Botanical Gardens, Tucson Children's Museum, Tucson Museum of Art, University of Arizona, U of A Mineral Museum. SANTA CRUZ COUNTY-Duquesne, Harshaw, Mowry, Hilltop Gallery, Old Courthouse, Old Red Schoolhouse, Pimeria Alta Historical Society Museum, Oro Blanco, Museum of the Horse Railroad / Station House, Patagonia-Sonoita Creek Sanctuary, Pena Blanca Lake, Smithsonian Astrophysical Observatory, Sonoita vineyards, Tubac Center for the Arts, Tumacacori Natural History Park, Washington Camp. COCHISE COUNTY -Cascabel Clay Works, Holy Trinity Monastery, San Pedro Valley Arts & Historical Museum, Bisbee Mining & Historical Museum, Bisbee Restoration Museum, Bisbee Visitor Center, Brewery Gulch, Copper Queen Hotel, Lavender Pit, Miners Homes Museum, Queen Mine Tour, Walking Tour of Historic Bisbee, Charleston, Cochise Stronghold, Contention City, Coronado National Memorial, Courtland, Dos Cabezas, Wells Fargo Station, Douglas Wild Animal Park, Amerind Foundation, Butterfield Stage Station ruins, Fairbanks, Fort Bowie National Historic Site, Geronimo Surrender Site, Gleeson, Hilltop, Muleshoe Ranch Preserve, Paradise, Pearce, Ramsey Canyon Preserve, Russellville, Slaughter Ranch, San Pedro Riparian National Conservation Area, Ft. Huachuca Historical Museum, Military Intelligence Corps Museum, Southwestern Research Station / American Museum of Natural History, Portal, Texas Canyon, Boot Hill, OK Corral, Rose Tree Inn Museum, Tombstone Courthouse State Historical Park, Tombstone Epitaph, Historic Railroad Avenue, Museum of the Southwest, Rex Allen Museum, Willcox Playa Wildlife Area. GRAHAM COUNTY-Black Hills, Joy Valley, Bonita Creek, Gila Mountains, Fort Grant, Fort Thomas, Indian Hot Springs, Mt. Graham Observatory, Museum of Discovery, Mt. Graham, Eastern Arizona Museum & Historical Society, Red Knolls, Safford-Graham Co. Library, Eastern Arizona College Museum of Anthropology, The Dunes, San Carlos Lake.

	GREENLEE COUNTY-Copperhead Locomotive, Greenlee County Historical Museum, Historic Chase Creek District Old Jail, Southern Pacific Depot, Coronado Trail, Dairy Tour, Morenci Open pit copper mine, Round Mountain, Yellow Jacket.
Wilderness Areas	Sycamore Canyon / Pajarita Wilderness Area, Aravaipa Canyon Wilderness Area, Pusch Ridge Wilderness Area, Rincon Mountain Wilderness Area, Pajarita Wilderness Area, Mt. Wrightson Wilderness Area, Miller Creek Wilderness Area, Galiuro Wilderness Area, Redfield Canyon Wilderness Area, Fishhooks Wilderness Area, Blue Range Wilderness Area, Peloncillo Mountains Wilderness Area, Chiricahua Wilderness Area.

4. Identification of Monitoring Needs, Triggering Mechanisms, Alert Levels, Roles and Responsibilities

This section will need to be developed in cooperation with the monitoring and the environmental health workgroup. Much overlap exists between the issues considered by Environmental Health, etc and the CRT workgroup.

5. Identification of Mitigation/Adaptation Options

Potential mitigation and adaptation options to consider include:

- Develop Local Community Mitigation and Response Plans – local communities that are depended on state or national parks for tourism could be asked to plan for future droughts to try to limit impacts.
- Enhance Public Outreach and Education at the state level to provide accurate information about the status of recreation and tourism sites. There is already excellent information on the USGS site about gage levels in various drainages, the ski areas post snow depth, etc., and forest closures are posted - but there could probably be a more comprehensive website or gateway for updated information on drought conditions, fire danger, etc.
- Develop recreation and tourism messages that emphasize the opportunities that still exist for recreation during drought, including enhanced programs for non-water based recreation in destinations that have traditionally focused solely on boating, rafting, or fishing, for example. Lengthen boat ramps to allow access to low-water reservoirs.
- To the extent possible, coordinate river releases during times when the maximum recreational benefits can be achieved.

- Evaluate ways to limit impacts of fire closures, such as allowing limited visitation in supervised hiking or rafting trips where leaders have radio contact.
- Enhance short-term drought- related conservation programs for potable water in communities that are key gateways to recreation and tourism sites to extend the availability of potable water. Provide pre-designed, camera-ready copy or free copies of drought-related messages to encourage foodservice operators, hotel managers, and visitors with conservation suggestions. For visitors, messages such as limit showers, reuse towels and linens, etc in hotels would be helpful.
- Have reduced campfire restrictions in areas that have water supplies on site, have full time site management, and have cleared vegetation in the vicinity of fire rings or grills.
- Because some park closures are water quality related, due to contamination of recreation sites and low flow volumes, there may be some water quality related mitigation and adaptation measures that could be identified.

6. Identification of Emergency Response Options

Emergency responses used in the past include forest and park closures, hunting and fishing restrictions, fire restrictions, hauling water, water use restrictions within communities and individual potable water companies, and public service messages. Many of these response options must be implemented by the agencies that manage the affected lands, including the National Forest Service, the National Park Service, the Arizona State Park System, etc. There may be opportunities for enhanced coordination of responses.

Attachment 1- Members of the CRT Workgroup

James Holt	Arizona Dept of Water Resources/Prescott Active Management Area
Carl Taylor	United States Dept of Agriculture/Forest Service
Ellen Bilbrey	Arizona State Parks
James Garrison	Arizona State Parks/State Historical Preservation Office
Annie Alvarado	Arizona Dept of Commerce/ Office of Rural Development
Levi Esquerra	Northern Arizona University/Center for Native American Indian Economic Development
Cheryl Cothran	Northern Arizona University/School of Hotel & Restaurant Management
Russ Tronstad	University of Arizona/College of Agriculture-Cooperative Extension office
Michael Leyva	Arizona Office of Tourism
Ginia Wickersham	Citizen

Attachment 2-CRT Sample Cover Letter and Survey Questionnaire

Sample Survey Cover Letter

(DATE)

(CONSTITUENT NAME)
(CONSTITUENT ADDRESS)

Dear (CONSTITUENT NAME):

The Governor's Drought Task Force, Commerce, Recreation & Tourism Working Group is conducting a survey of stakeholders to identify and rank the major economic impacts of drought and identify other organizations who have or are currently working on economic issues related to drought in Arizona.

The mission of the Governor's Drought Task Force is,

"To develop a sustainable drought planning process for Arizona which will include:

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

As a member of the Commerce, Recreation & Tourism Work Group, I am interested in obtaining feedback, or data from you pertaining to this mission. You and your organization are key stakeholders. Your feedback is important to help us produce information that will serve your needs in the format that works best for you.

Please take a few minutes to fill out the enclosed survey. You may complete the survey electronically and after saving it with a new name you can return it by simply attaching it to an email to dtf@adwr.state.az.us. Of course you may choose to print the survey and complete it manually. If so, please mail it to:

Governor's Drought Task Force
c/o Carol Young, Administrative Assistant
500 N 3rd Street
Phoenix AZ 85004-3903

Kindly return the survey by **February 1, 2004**. Your responses will be kept confidential.

We greatly appreciate your participation. You may obtain more information regarding the work of the Governor's Drought Task Force at http://www.water.az.gov/gdtf. Please do not hesitate to contact me if you have any questions at (YOUR PHONE) or (YOUR EMAIL).

Thank you for your time and help.

Governor's Drought Task Force

COMMERCE, RECREATION & TOURISM WORK GROUP SURVEY FORM

James Holt
Arizona Department of Water Resources
Area Director, Prescott Active Management Area
928-778-7202 928-776-4507 (F)
jhholt@adwr.state.az.us

Robert Detweiler
Arizona Department of Commerce
Rural Economic Development
602-771-1135 602-771-1210(F)
robertd@azcommerce.com

Assessment of Actual/Potential Drought Impacts

Please provide your assessment of *negative* impacts associated with long-term drought. List the top three negative drought impacts you have experienced or observed that have affected you or businesses in your area.

Please also identify the secondary or less obvious negative impacts associated with long-term drought that you may have experienced or observed.

How might a coordinated drought plan acknowledge and attempt to deal with the negative impacts you have identified?

Background Information

Please list research, studies or assessments that you feel might be useful to the work of the Governor's Drought Task Force. Provide the following information for each:

- Title
- Author(s)
- Where published
- How these publications may be accessed

Title	Author	Publisher	Source

(Follow this format for additional recommendations if listed on attachments)

Please list any useful web sites. Provide the following information for each:

- Name of web site
- Type of information provided
- Any comments (i.e., if the site is difficult to navigate, frequency information is updated, other information the work group would find useful)

Web Site	Type of Information	Comments

(Follow this format for additional recommendations if listed on attachments)

Participant Recruitment

Can you identify two individuals from the commerce, recreation, and tourism sectors that should be encouraged to participate in the Drought Task Force process?

Participant One

- Name:
- Organization:
- Contact information:

  Indicate whether this person would be best positioned as (select *only one*)
  (a) ☐A member of the task team (b) ☐A technical advisor
  (c) ☐An outside reviewer of the plan (d) ☐A participant in public meetings
  (e) ☐Other (specify)

- What area(s) of knowledge/expertise is this person likely to provide?

- What strategy might we use to recruit this individual?

- Once the Drought Plan is completed, what role might this person play in ongoing drought monitoring and response?

Participant Two

- Name:
- Organization:
- Contact information:

  Indicate whether this person would be best positioned as (select *only one*)
  (a) ☐A member of the task team (b) ☐A technical advisor
  (c) ☐An outside reviewer of the plan (d) ☐A participant in public meetings
  (e) ☐Other (specify)

- What area(s) of knowledge/expertise is this person likely to provide?

- What strategy might we use to recruit this individual?

- Once the Drought Plan is completed, what role might this person play in ongoing drought monitoring and response?

(Follow this format for additional recommendations if listed on attachments)

Geographic Information

In what region of the state do you reside, conduct business or do research?

Region

1. ☐
2. ☐
3. ☐
4. ☐
5. ☐
6. ☐
7. ☐

Optional Information

Your Name:
Name and type of organization or business:

- ☐ Commerce
- ☐ Recreation
- ☐ Tourism

Address:
Telephone Number:
E-mail address:

In the following terms, if applicable, how would you describe your organization:

- ☐ User days:
- ☐ Population Served:
- ☐ Annual Visits:
- ☐ Annual Revenue:

Attachment *2*-Summary of Results - Commerce, Recreation and Tourism Survey
January 2004

	Primary negative impacts of long-term drought that you have experienced or observed.	**Secondary or less obvious impacts of long-term drought.**	**How might a coordinated drought management plan acknowledge or deal with negative impacts of drought.**
Climate Division 1	• Lake Havasu has yet to experience negitive impact from drought conditions.		
Climate Division 2	• Negative media attention concerning water levels in Lake Powell has impacted the water user of our tourism segment • Negative media and attitudes to the bleached sandstone exposed as water levels have receded has impacted the "scenic area/photographer" of our tourism segment • Negative media concerning the long-term drought predictions has caused potential visitors to Lake Powell to change their future plans because of the impression that there will not be any water in the lake in the future either.	• There have been impacts to the marinas as they have had to move further away from their utility bases, parking lots, and customer service centers. There are also issues with closed boat ramps, closed beaches, and water hazards that have been exposed as lake levels recede. • Many scenic areas that were readily accessible only by boat are now no longer accessible. • Boat tour routes have been adjusted to accomdate lower lake levels and have had to drop some scenic areas from their iteneraries. • Hite Marina has been closed because the lake level has receded so far from services. Bullfrog and Halls crossing marinas have had to create alternative marina plans for boat storage, fuel docks and services.	• I think that a plan that is coordinated would present a united and consistent approach to the media, which could lessen the impact of negative presentation of the situation to the public. • It would also present to the general user of the resources that people are aware of the problem of drought, and are trying to deal with the impact of it.
Climate Division 2	• Payson's limited water supply, whether it be considered drought related or not, has been one of the greatest obstacles to economic development in the community.	• Since Payson is located in the forest, it has additional impact from the drought. Fire is a constant threat and rumored and/or actual forest closures are very damaging to our	• There is sufficient water in the Payson area, however all surface water (including the rain and snow that falls on our own homes, streets and businesses) is claimed by SRP.

	Primary negative impacts of long-term drought that you have experienced or observed.	Secondary or less obvious impacts of long-term drought.	How might a coordinated drought management plan acknowledge or deal with negative impacts of drought.
	• Innumberable industrial, residential and hospitality projects have been halted due to water issues.	businesses and general economy. • The drought has allowed bark beetles to kill thousands, if not millions, of trees increasing the fire danger and destroying the estetic appeal of the forest. • Thinning and fire prevention measures, not tomention the efforts to get these authorized, take funds and other resources that could otherwise be used for other more productive projects. • Additionally, as our lakes and streams dry up we loose visitors who come to fish, boat, etc. affecting our tourism industry.	• Payson is taking drastic conservation measures while we see continued wasting of water in the Phoenix area. • Coordinating water usage and conservation efforts would be beneficial to our community. • Also, cooperating with all forested Arizona areas to promote forest thinning for fire prevention and the health of the remaining trees.
Climate Division 2	• Lack of moisture has caused closures of national forest lands, thus impacting tourism numbers. • In the winter, drought conditions have caused delays in opening of ski areas in the state, again impacting tourism numbers.	• Because the drought is newsworthy, many articles about the drought cause secondary negative impacts by causing readers/viewers to question their vacation plans in drought areas. Cumulative effect is of concern.	• Put positive spin on the majority of events and activities around the state that are not related to drought conditions.
Climate Division 3	• Water tables (access to water for growing population) • Fire Danger to region • Loss of forest	• Without water all economic growth may be impacted • Loss of tourist dollars. • Danger to Ranching, cattle, vegetation	• Focused need for a regional/state-wide water plan is critical for all of Arizona (not just the Valley) • Drought will have long-term tourist impacts as well as corporate locations (no-water, no business)

	Primary negative impacts of long-term drought that you have experienced or observed.	Secondary or less obvious impacts of long-term drought.	How might a coordinated drought management plan acknowledge or deal with negative impacts of drought.
Climate Division 6	• Wildfire problems in Northern AZ impacts travel to the state • The desert, one of our main attractions, does not look as lush as in the past • It is difficult to beautify with landscaping. • Since Tempe is an older community, most of the vegitation is non-desert plant life. Is will be expensive to change from lush to desert landscaping.	• Continues wildfire conditions threaten the state meaning loss of service industry jobs • Negative publicity of wildfires hampers efforts for tourism promotion even though the fires are more than 100 miles from the metro area • Continued sprawl with more asphalt, homes and cars will continue to create even more hotter than normal temperatures beyond just the summer. If the heat increases, the Arizona may become too hot for travelers and we could lose market share.	• I believe it is well overdue for the state to do something about the insane growth patterns and the problems associated with the warmer temperatures. • I believe that solutions need to be found such as an alternative to the hot, black asphalt. Are there alternatives to this material that would lessen the heat given off by the asphalt? • Is there a way to legislate the types of plants being used in developments? Can the state use incentives to get residents to change out their lawns from grass to desert?
Climate Division 7	• No water for the cattle or wildlife equals decreased economic factors in the ranching and hunting/recreation communities. • (These effects) filter down to local community business and banking loss. • As ranches go under open spaces decreases as ranches are sold to developers. • Mismanaged ranches and wildlife populations (no droughht plan) damage the resource.	• Nutrition in the grass is poor, biodiversity suffers, distance between plants increase, and erosion starts. Then this process snowballs. • Loss of herd genetics, which take years to develop. • Most cattle are held untill the last moment by ranchers and when all these cattle hit the market at the same time, the price naturally goes down. • Range improvments are allowed to deteriorate due to lack of economic viability.	It would of course solve the above!!!!!!!

	Primary negative impacts of long-term drought that you have experienced or observed.	Secondary or less obvious impacts of long-term drought.	How might a coordinated drought management plan acknowledge or deal with negative impacts of drought.
Climate Division 7	• Loss of cattle revenue • Loss of guest & tourism revenue (hunting/ dude ranch) • Increased fire hazards	• Whenever drought is broken it will take several years for vegetation to attain good growth. • Loss of timber in marginally wet areas will cause fire hazards.	• Whenever we as ranchers show a decreased income, the state looses revenue from taxes, leases, permits, etc. • Banks are not prone to lend money in a crisis that they have overextended. • Everyone needs to budget for disasters as this.

Appendix VIII
WORKGROUP REPORT – ENVIRONMENTAL HEALTH, WATERSHED MANAGEMENT, LIVESTOCK & WILDLIFE

Arizona Drought Preparedness Plan
Environmental Health, Watershed Management, Livestock, and Wildlife

WORKGROUP REPORT – **DRAFT** 08-24-04

I. BACKGROUND

Although located in an arid region, Arizona's ecology is made up of very diverse and unique plant and animal communities that provide aesthetic, recreational, and economic value to residents and visitors alike. The development of water supplies in this State have been aimed at providing an adequate, long-term supply of good quality water for agricultural production, for drinking water and for industries that are supporting the economic base of this State. However, the biotic communities are dependant on the available water supplies and local precipitation to meet their requirements as well. Additionally, the importance of these communities in maintaining a healthy ecosystem is of importance to the water management goals of this State as they directly impact the ability to provide a high quality long-term supply to the people of Arizona. Because these sectors typically share common resources, which commonly are the first to be impacted by drought, the Governor's Drought Task Force created the Environmental Health, Watershed Management, Livestock and Wildlife Workgroup to evaluate drought impacts and based on these impacts, develop a strategy to identify drought at its early stages to protect those most important to the State of Arizona.

This chapter will describe the importance of Arizona's biotic communities, the relationship of these communities to the industries that are dependant upon these, the impacts that drought has had in the past on the watersheds that comprise these communities, and the vulnerability of these communities to future droughts. As a result of the initiation of the Governor's Drought Task Force, a monitoring network will be developed to continually assess the conditions of these resources to provide land managers and decision-makers with adequate warning of impending drought conditions in order to adapt their management practices to maintain the ecological and economic viability of these communities. To meet this objective, the workgroup has identified the primary indicators necessary to identify the onset of drought conditions. Finally, adaptation, mitigation, and response options will be described in order to provide guidance and options to reduce the impacts of drought and to respond to immediate issues associated with extreme drought conditions.

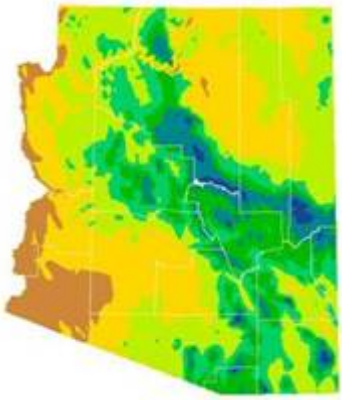
Arizona Topography

Arizona covers 113,909 square miles, with about 350 square miles of water surface. The state has three main physiographic regions:
(1) the Colorado plateau region in northeastern Arizona with elevations generally ranging from 5000 feet over 12,600 feet;
(2) a mountainous transition zone oriented northwest to southeast through the central portion of Arizona with elevations ranging from about 3000 to 5000 feet; and
(3) a desert basin and range region with elevations generally ranging from 100 to 3000 feet in southwestern and western Arizona.

The highest point in the state is Humphrey's Peak, located northwest of Flagstaff, with an elevation of 12,611 feet.

Baldy Peak in the White Mountains of eastern Arizona is the second highest peak in the state with an elevation of 11,490 feet.

Arizona Climate



Precipitation throughout Arizona is governed to a great extent by elevation and season of the year. From November through March, storm systems from the Pacific Ocean cross the state. These winter storms frequently produce precipitation in the higher mountains of the central and northern parts of the state, often bringing heavy snowfall. Snow accumulation may reach depths of 100 inches or more during the winter. The gradual melting of the winter snow cover during spring serves to maintain a supply of water in the main rivers of the state. Reservoirs on the streams and rivers supply water to the desert areas in the lower Salt River Valley and the lower Gila River Valley areas, both of which are extensively farmed.

Summer rainfall begins early in July and usually lasts until mid-September. Moisture-bearing winds move into Arizona at the surface from the southwest (Gulf of California) and aloft from the southeast (Gulf of Mexico). The shift in wind direction, termed the North American Monsoon, produces summer rains in the form of thunderstorms that result largely from excessive heating of the land surface and the subsequent lifting of moisture-laden air, especially along the primary mountain ranges. Thus, the strongest thunderstorms are usually found in the mountainous regions of the central and southeastern portions of Arizona. These thunderstorms are often accompanied by strong winds and brief periods of blowing dust prior to the onset of rain. Hail occurs rather infrequently.

The average number of days per year with measurable precipitation varies from near 70 days in the Flagstaff area to 15 at Yuma. A large portion of Arizona is considered to be of a semiarid climate type and extended periods of little or no precipitation are common. The atmosphere is generally dry and clear with low relative humidity and a high percentage of sunshine. The months with the greatest number of clear days are April, May, and June, while July, August, December, January, and February are the months with the lowest percentages of possible sunshine. Humidity, while relatively low, is higher throughout much of Arizona during July and August. Annual average relative humidity values range from 55% at Flagstaff to approximately 33% at Yuma. Yearly averages of percent of possible sunshine range from 86% to 92%. Due to high air temperatures, low humidity values, and the higher percentage of sunshine across the state, statewide evaporation rates are high. Mean annual lake evaporation varies from about 50 inches in the northeastern portion of the state to about 80 inches across the southwest.

The higher elevations of the state, the Colorado Plateau, running diagonally from the southeast to the northwest, average between 25 and 30 inches of precipitation (rain plus snow water equivalence) annually, while the desert southwest averages as low as three or four inches per year. The northeastern corner of the state receives approximately 10 inches of precipitation annually.

Winter season cold air masses from Canada occasionally penetrate into the state bringing air temperatures well below zero in the high plateau and mountainous regions of central and northern Arizona. Historically, the lowest air temperature readings have reached –35°F. High temperatures are common throughout the summer months at lower elevations. Temperatures exceeding 125°F have been observed within the desert areas. Great extremes in air temperature occur between daytime and nighttime hours throughout Arizona. The range in daily maximum and minimum temperatures occasionally exceeds 50°F during the drier portions of the year. During winter months daytime temperatures may average 70°F while nighttime temperatures often fall to freezing or slightly below in desert valleys. During summer the pine forests in the central portion

of the state may exhibit afternoon temperatures of 80°F while nighttime temperatures drop to 35-40°F.

The length of the growing season (period between freezes) varies tremendously over Arizona, averaging less than three months in some of the higher areas in the northern and eastern portions of the state. Opposite to this is the sometimes several years between freezes in some of the desert valleys.

Historical data has provided much insight into Arizona's climate history. Much of this data comes from tree ring research and pack rat middens (Swetnam and Betancourt 1990). Along with precipitation, fire scars and evidence of insect outbreaks have allowed much our natural history to be re-created, increasing our understanding of the past. The Climate Assessment for the Southwest (CLIMAS) project was established "to assess the impacts of climate variability and longer-term climate change on human and natural systems in the Southwest." Combining tree ring data with the instrumental record, CLIMAS has documented much of the past thousand years. Most tree or woody growth occurs in response to cool season precipitation. Winter or cool season precipitation is mostly responsible for recharging groundwater, therefore raising water tables, while the summer or warm season precipitation tends to drive production of many forbs and grasses. Thus, data from tree rings reflect cool season precipitation rather than year round. Research also demonstrates that spatial and temporal variability of precipitation is also a major determiner driving ecosystem response and should be taken into account in management decisions.

CLIMAS has identified periods of drought for the entire state of Arizona based on four-year precipitation totals as well as several extended periods of drought. Four-year totals showed the periods 1148-1151, 1215-1218, 1668-1670, and 1779-1782 with 52%, 49.1%, 47.1%, and 54%, respectively, as the driest years based on average precipitation. There were also three extended droughts worth noting. These occurred from 1571-1598 (28yrs), 1654-1671 (18 yrs), and 1773-1790 (18 yrs). Only 3 years combined from all three extended droughts were normal or above normal precipitation and with a combined 36 years of less than 75% of average precipitation (CLIMAS).

The past century has also seen several periods of drought conditions. The three driest years on instrumental record were 1904, 1972, and 2002, which received 16.1%, 30.5%, and 27.5% of average precipitation. The driest four year periods of the last century were 1901-1904, 1954-1957, 1969-1972, and 1999-2002. Precipitation for these periods totaled 60.2%, 64.4%, 63.8%, and 57% of average, respectively.

Watersheds

The term watershed has been defined many ways, some of which can be rather technical in nature. Most definitions, however, maintain a central theme. A watershed is the drainage area that contributes water to a river, lake, or another body of water. A watershed includes all the "land area from which surface water and groundwater drains into a stream system (the area of land that generates total runoff (surface flow, interflow, and baseflow) for a particular stream system" (Schmidt 2004). It is "the area of land above a given point on a stream that contributes water to the volume of a body of surface water" (Pye 2003). Another definition goes even farther, stating a watershed as "consists of all the land and waterways that drain into the same body of water. Smaller watersheds join with other watersheds to drain into larger watersheds; thousands of smaller watersheds drain into large rivers like the Mississippi or Colorado rivers" (Collins 2003). Many of these larger watersheds may also be referred to drainage basins. The map (Figure 1) on the following page illustrates the drainage basins that occur in Arizona.

A watershed, like anything else, can be in good or bad condition and management strategies or lack thereof will largely determine their health. A healthy watershed is important in helping to ensure ecosystem balance. Watersheds are essential for the storing and releasing of water, the cycling of nutrients, the filtering of sediments and pollutants, and also provide critical habitat and valuable water supplies for communities throughout Arizona.

Figure 1: *Taken from*: University of Arizona Cooperative Extension *http://ag.arizona.edu/watershed/*

The functionality of a watershed is determined largely by the lay the land. Climate along with elevation, slope, and aspect determine when and where the water moves. As water moves through the system, it assists in such processes as soil formation. Soil is an ecosystem in itself and its flora and fauna are responsible for the breakdown and subsequent uptake of nutrients in organic matter. Soil determines the plants that grow as well as the rate at which water flows or percolates beneath the surface.

Vegetation also plays an important role in the health of a watershed. Trees, shrubs, and grasses act as shields and windbreaks, protecting soils from splash and wind erosion, respectively. Roots bind the soil and help contribute to soil structure, while litter from vegetation protects the soil surface by slowing overland flow. These plants also provide habitat and food for all animals living within or moving through these watersheds.

Watersheds in poor health may exhibit high rates of overland flow causing erosion and at times mass wasting. This loss of soil is important, because it is practically non-renewable. With a loss of soil comes a loss in fertility. The top layer or horizon of soil is typically the most nutrient rich. Depth of soil is also affected when this top layer is eroded. The loss of soil could cause an inability to regenerate by many species and therefore a loss of plant diversity and cover. Surface waters are also affected as sediment loads increase in streams, rivers, and lakes. Increased turbidity (i.e. cloudiness) contributes to a decline in water quality including a drop in dissolved oxygen. A watershed in an unhealthy condition will continue on a downward spiral further contributing to a decline in habitat and food source for all species present.

Wildlife

Wildlife species in Arizona are just as diverse as its topography. The wide range of elevation and the availability of surface water in this arid region provide habitat to many species, migratory or resident. Band-tailed Pigeon, Blue Grouse, Cottontail Rabbit, Mourning Dove, White-winged Dove, Pheasant, Quail, Sandhill Crane, and tree squirrel compose the states main small game species. The major big game species include Antelope, Black Bear, Buffalo, Desert Bighorn Sheep, Elk, Javelina, Merriam's Turkey, Mountain Lion, White-tail Deer, and Mule Deer. Also, many migratory waterfowl inhabit the state at a given time. Waterfowl of mention are American Widgeon, Blue-winged Teal, Northern Shovler, Bufellhead, Canvasback, Canada Geese, Cinnamon Teal, Common Merganser, Gadwall, Green-winged Teal, Mallard, Pintail, Redhead, Ring-necked Duck, Ruddy Duck, and Lesser/Greater Scaup (Arizona Game and Fish). Migratory Neotropial songbirds and shore birds also contribute to Arizona's bio-diversity. Arizona is also

home to many threatened and endangered species. Attachment I illustrates the threatened and endangered species that can be found in Arizona.

Wildlife in Arizona provides valuable aesthetic and economic importance to Arizona and also contributes to the biodiversity of the state. Many species are native to the region are important symbols to the southwest. Additionally, big and small game animals and aquatic species provide recreational opportunities to sportsmen (and sportswomen) across the State. The Arizona Game and Fish Department manages and protects wildlife across the State and Arizona is home to nine Wildlife Refuges, managed by the U.S. Fish and Wildlife Service.

Livestock

Over two- thirds of the land area in Arizona is classified as rangeland. Cattle first arrived in the southwest in 1540, as Coronado made his journey northward through present-day Arizona. It was not until 1670 to 1690, though, when missionaries were established throughout the southwest and livestock husbandry (cattle, hoses, sheep, and goats) became increasingly present on the landscape and in the culture. Missions were established in what are now Arizona, Texas, New Mexico, and California. These missions would later become livestock centers.

By 1875, livestock husbandry was one of Arizona's leading industries. The Southern Pacific Railroad, completed in 1881, and the Atlantic and Pacific Railroad, a year later, opened up even more of the territory for ranching, especially the central and northern areas where rainfall was more abundant. In 1891, nearly 721,000 head of cattle were registered for tax purposes, yet it was commonly believed there was actually twice that number on the ranges (Tonto National Forest 2003).

It was 1905 before the U.S. Forest Service adopted an allotment and permit system for livestock. By the early twentieth century, livestock populations had increased significantly and up until this time there had been no regulations on grazing. In an attempt to allow the land rest, the U.S. Forest Service devised an allotment system to be used on all public grazing lands. The demand for beef increased with the onset of World War I, and many ranges were stocked with extremely high numbers despite poor range conditions. (Tonto National Forest 2003). In 1934, the Taylor Grazing Act was signed into law. This act set aside any lands that were not already accounted for as “public domain”. The Taylor Grazing Act also called for the creation of the Grazing Service, later to be known as the Bureau of Land Management (BLM), which would manage these public rangelands in a sustainable fashion. The BLM followed suit with the Forest Service and permits were issued for the right to graze (Fleischner 2002). Federal lands now account for over 65 percent of Arizona’s grazing capacity outside of Indian reservations”(Tronstad and Feuz 2002). The Arizona State Land Department also accounts for nearly nine million acres of Arizona’s grazing land, however, state land is not considered to be a public entity, rather it is land which has been set aside to be leased whereby the monies are be used to benefit public education in Arizona. These three agencies control approximately 20% (Forest Service), 16% (Bureau of Land Management), and 13% (Arizona State Land Department) of all land in Arizona, respectively – approximately 28 million acres for livestock grazing. Indian reservations also account for 27% of lands in Arizona while the remaining 24% is split between individual/corporate owners (17%) and other public lands (7%) (National Agricultural Statistics Service 2002).

Cow/calf operations dominate Arizona cattle ranches. These operations are characterized by a herd of breeding females and a few bulls, and produce calves that are sold each year after weaning or as yearlings for beef production. The base herd is usually comprised of animals that are considered to be marketable as well as being suited to the terrain of the ranch. Stocker operations that include steers, which are marketed for beef production, are also operated to a lesser degree in Arizona. Although some ranchers have access to groundwater pumped from wells, most ranches in Arizona are dependent on precipitation as their main source of water,

utilizing stock tanks to capture precipitation to carry them through the season. Because of the spatial variability of precipitation, as well as the seasonal variability, ranchers utilize various grazing systems to take advantage of available, good quality forage to meet the needs of their herds. Grazing systems used in Arizona must be adaptable to the climatic variability of the region. According to the Arizona Interagency Range Committee (1973), there are several basic systems for Arizona Ranges as described in Table 1 below.

TABLE 1: Grazing Systems in Arizona

Grazing Systems	Description
Rest-Rotation Grazing Systems	The range is divided up into pastures or units. Each unit is systematically grazed and rested in set intervals.
High-Intensity-Low-Frequency Grazing Systems	The range is divided up into pastures or units. Animals are moved from one pasture to another when a desired level of forage is utilized.
Year-long Ranges (System 1)	3 pasture rest-rotation system in which the range is rested March to October 2 years out of 3, with winter grazing only between the two spring summer rest periods.
Year-long Ranges (System 2)	3 pasture rest-rotation grazing system in which the pasture grazed first is given 16 months rest while the other two pastures are grazed during the latter part of the growing season
Summer Ranges	3 pasture rest rotation system in which a given pasture is rested all season for the first year, rested the second half of the season the next year, and rested the first half of the season the next year, before starting the process.
Winter-Spring Ranges	Requires several winter pastures and several summer pastures. Pastures in each seasonal unit are rested alternately- early in season one year and late in season next year.

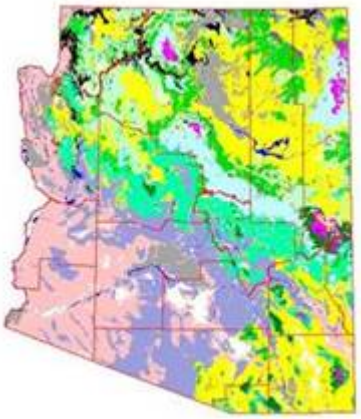
Stocking rates are also extremely important to the productivity and vitality of rangelands. Forage availability should define the stocking densities. Martin and Cable (1974) suggested stocking rates at or below 90% of average long-term carrying capacity, while making adjustments accordingly. Howery points out that as drought intensifies the options available to land managers decline, making it very important to monitor monthly trends in environmental variables at several key locations. “A higher diversity of plants, including warm and cool season grasses, yield better range conditions. The intensity, timing, and frequency of grazing controls the extent to which the drought affects the range’s potential. Moderately grazed grasses can still extract soil moisture when it drops to 1-2%, yet heavily grazed may wilt permanently at 6-8%. Plants which are grazed repeatedly when they are photosynthetically active may become stressed and have no time to grow new sprouts between defoliations” (Howery).

II. REGIONAL VULNERABILITY

Drought is an important part of the ecology in the southwest and plays an important role in the development of the diversity of animal and plant communities that are part of our environment. Probably the earliest impacts of drought can be seen in the sectors that are described in this report. Factors that influence vulnerability in these sectors include climate, access to resources, management practices, and other human activities. Although several State, Federal and Tribal agencies are responsible for managing these resources in the State of Arizona, along with activities that occur on private lands, the influence of humans has increased the vulnerability of the lands and wildlife in the State. These agencies are striving to mitigate past impacts to the environment and have modified their policies and practices to improve the environmental conditions. Land management practices on public and private lands that influence vulnerability include timber production and harvesting, mining activities, fire management and suppression, recreational activities, and livestock grazing. Other human activities that influence vulnerability in these sectors include urban development, construction of transportation corridors, and development of rights of way for power and water supply distribution. These activities alter the landscape, create competition for resources, alter species diversity, reduce habitat availability, and disrupt migratory corridors for wildlife all of which increase vulnerability to reduced resources in times of drought.

Because these sectors are so dependent on climate, vegetation, and natural water systems, the workgroup is using ecological descriptions that have been developed for Arizona by the Natural Resources Conservation Service to provide an overview of the potential vulnerability to drought to wildlife, livestock and the ecosystems of this State. This section will describe the vegetation, key wildlife species, and land use practices for each eco-region within the State of Arizona.

Arizona Vegetation



Arizona's vegetation is extremely diverse due to the elevation and topography extremes within the state. The state's vegetation is influence by 4 major deserts, the Sonoran Desert in southwest Arizona, the Mohave Desert in Northwest Arizona, the Chihuahuan Desert which largely occurs in New Mexico and Mexico to the southeast of Arizona, and Great Basin Desert which influences the vegetation on the Colorado Plateau. The top of Mount Humphrey is above the timberline, with alpine tundra vegetation. Arizona has the largest continuous stand of Ponderosa Pine forest in the United States, which occurs along the Mogollon Rim. The transition area below the Mogollon Rim supports unique interior chaparral shrub communities that mix with the desert and grassland vegetation at the lower elevations, and with the coniferous forests at the higher elevations.

Major Land Resource Areas are the broad bio-geographic regions differentiated by geology, climate, and vegetation. Major Land Resource Areas or ecoregions in Arizona include the following:

- Sonoran Desert
- Mohave Desert
- Colorado Plateau
- Mogollon Coniferous Forests
- Mogollon Transition
- Madrean Basin and Range

Each of these Major Land Resource Areas are further subdivided into resource areas based primarily on elevation and precipitation zones which tend to support different kinds and amounts of vegetation, wildlife, and land uses which are affected by drought in different ways.

Sonoran Desert

Three resource areas have been identified in the Sonoran Desert region.

Upper Sonoran Desert

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, lacustrine, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from about 2000 to 3200 feet. Precipitation averages 10 to 13 inches per year. Snow is rare and seldom lasts more than an hour or two.

Vegetation is dominated by desert shrubs, trees and cacti. Deep, upland sites have overstories of mesquite, littleleaf paloverde, and ironwood, with understories of perennial and annual grasses and forbs. This Resource area supports the highest densities of Arizona's famous Saguaro cactus. It also support a wide diversity of opuntias (cholla and prickly pear species) and other cacti on the uplands and hill slopes. Bush muhly is the dominant perennial grass. Other grasses include slender grama, purple threeawn, mesa and spidergrass threeawns, Arizona cottontop, Pima pappusgrass, red grama, slim tridens, and fluffgrass. Major forbs include slender janusia, twinberry, spiny goldenhead, desert globemallow, and yerba del venado. Triangle bursage is the dominant half-shrub in this area. Other shrubs include jojoba, false mesquite, desert zinnia, mormon tea, creosote bush, flattop buckwheat, ocotillo, limberbush, and wolfberry species. Club moss is a very important plant on the hills, and can make up as much as half of the plant composition on the cooler, north facing slopes. Annual grasses and forbs of both winter and summer seasons are well represented in years with favorable moisture.
Wildlife species include javelina, desert mule deer, desert bighorn sheep, Gambel's quail, mourning and whitewing dove, jackrabbits and cottontails.

The Verde and Gila rivers are the only perennial streams that flow through this resource area. Portions of the San Pedro and Santa Cruz Rivers have perennial water supplied by springs. Other major drainages include portions of the Agua Fria River, and Brawley Wash. All of the lakes in this resource area are man-made. They include Horseshoe Reservoir, Bartlett Reservoir, Canyon Lake and Saguaro Lake. The water supply for wildlife and livestock in this resource area is mostly from pumped underground supplies. Although there are some stock ponds in this resource area, the low annual rainfall makes them unreliable unless they capture water from large watersheds or they are located adjacent to bedrock slopes that produce higher runoff during small storm events. The water is generally of good quality, although a few areas of groundwater with high salt and mineral content occur along the San Pedro river.

Recreation is an important use of this resource area. Hiking, camping boating and hunting occur in and around Bartlett and Horseshoe Dams, Hells Canyon Wilderness, the Roosevelt Lake Wildlife Area, the Superstition Wilderness, White Canyon Wilderness, Needles Eye Wilderness, Table Top Wilderness, Saguaro Wilderness, and portions of the Buenos Aires National Wildlife Refuge. This resource area includes the Cave Creek Recreation Area, McDowell Mountain Recreation Area, Boyce Thompson Arboretum State Park, portions of Tonto National Forest, Catalina State Park, portions of Coronado National Forest, Saguaro National Monument, Tucson Mountain Park, and the lower elevations of the Santa Rita Experimental Range. The reservoirs provide most of southern Arizona's fishing opportunities.

Most of this resource area is used for cattle ranching. Cow-calf and steer operations are the two dominant kinds of livestock operations. The number of livestock fluctuates significantly between years of good precipitation and dry years. Long term stocking rates are generally between 4 and 8 head per section (640 acres).

Middle Sonoran Desert

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from about 1200 to 2000 feet. Precipitation averages 7 to 10 inches per year. Vegetation includes saguaro, creosote bush, triangle bursage, brittlebush, and cholla. Wildlife species include javelina, desert mule deer, desert bighorn sheep, Gambel's quail, mourning and whitewing dove, jackrabbits and cottontails. The vegetation and wildlife in this resource area are well adapted to very dry conditions and have developed mechanisms to cope with long periods without rainfall. Inter-spaces between woody species and cacti on the uplands are typically bare, but can become completely covered with annual grasses and forbs during years when rainfall is abundant.

Major urban areas include the Phoenix metropolitan area and Casa Grande. Smaller communities include Sacaton, Coolidge, Florence, and Cave Creek. Other interesting areas include the Organ Pipe Cactus National Monument, and Picacho Peak.

Vast, level basin floors are bisected only by the major axial streams like the Salt, Santa Cruz and Gila Rivers. The floodplains of these rivers are moderate in width varying from 2 to 10 miles. The water supply for wildlife and livestock in this resource area is mostly from pumped underground supplies. Although there are some stock ponds in this resource area, the low annual rainfall makes them unreliable unless they are very large or they are located adjacent to bedrock slopes that produce higher runoff during smaller storm events. Water supplies, in general , are adequate and of good quality, even though groundwater levels are dropping.

Most of this rangeland is grazed seasonally with stocker cattle in years with good winter -spring rainfall. There are a few cow-calf operation. Stocking rates must be determined year to year but the long term average for yearlong grazing is 2 to 5 head per section.

Lower Sonoran Desert

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from about 300 to 1200 feet. Precipitation ranges from 3 to 7 inches per year.

The vegetation and wildlife in this resource area are well adapted to extremely dry conditions and have developed mechanisms to cope with long periods without rainfall. This resource area seldom experiences freezing temperatures, and as a result, vegetation can grow throughout the year whenever soil moisture is available. Vegetation includes creosote bush, white bursage, brittlebush, and smoke tree. Threeawns, bush muhly and big galletta are important grass species, but they are only present on the most favorable sites. Woodlands along the Colorado River and Gila River are dominated by screwbean mesquite, velvet mesquite, Fremont cottonwood and black willow. Salt cedar has become entrenched along the river bottoms. Inter-spaces between woody species and cacti on the uplands are typically bare, but can become completely covered with annual grasses and forbs during years when rainfall is abundant. Vegetative production averages about 200 pounds per acre per year on the uplands.

Important wildlife species include Sonoran pronghorn antelope, quail, rabbits, coyotes, and a variety of lizards, snakes, and burrowing rodents.

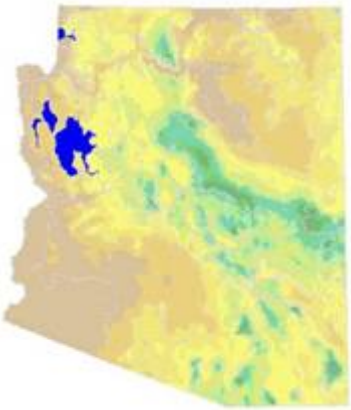
The southern and western part of this resource area is not grazed, and grazing in the eastern portion is limited to winter-spring use by stocker cattle only in years with favorable cool season rainfall. Stocking rates must be determined each year, and grazing may only be feasible 5 years out of 10.

Mohave Desert

Three resource areas have been identified in the Mohave Desert region.

Upper Mohave Desert

This resource area is characterized by numerous mountain ranges above broad valleys and basins. Igneous and metamorphic rock classes dominate the mountain ranges. Elevations range from mostly from 3500 to 4500 feet with isolated mountain peaks reaching 6500 feet. Precipitation averages 10 to 14 inches per year with up to 18 inches per year on the highest peaks within the Mohave Desert region.



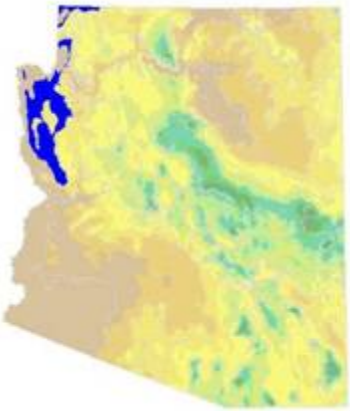
Vegetation includes Joshua tree, blackbrush, Mormon tea, ratany, bush muhly, galleta, and black grama. Blackbrush is dominant on many sites. Taller shrubs include creosote bush, Anderson wolfberry, and desert almond. Joshua tree and agave species can be common on some sites. Perennial grasses increase in amount and diversity of species compared to lower resource areas. Some upland sites will support a mixed grassland-shrub community at the higher elevations. Bottom sites can contain fourwing

saltbush, shadscale, and alkali sacaton. On the highest peaks of isolated mountains within the Mohave Desert region, chaparral species, pinyon, juniper, and ponderosa pine occur.

Mammals in the Mohave Desert include desert bighorn sheep, mule deer, cottontail rabbits and a variety of small rodents including the Merriam kangaroo rat, little pocket mouse, whitetailed antelope squirrel, and desert woodrat. Populations of wild burros occur in some areas. Chuckwallas, Iguana, and other lizards are common. The yucca night lizard lives in and under rotting Joshua trees and in nests of the desert packrat. Snakes include kingsnakes, whipsnakes, and rattlesnakes.

Middle Mohave Desert

This resource area is characterized by broad valley plains, alluvial fans, and hills. Sediments are fluvial, lacustrine, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from about 1500 to 3500 feet. Precipitation averages 6 to 10 inches per year.



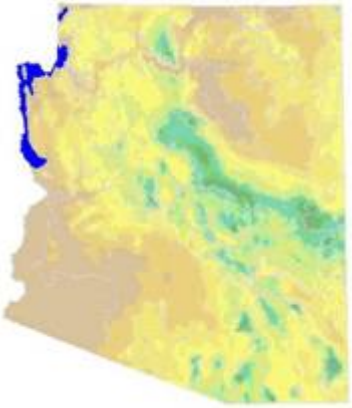
The vegetation is a mix of desert shrubs and grasses. Creosote bush is the dominant shrub on many sites. Blackbrush can dominate some upland soils in the northern portion of the area. Others include Mormon tea, flattop buckwheat, ratany, winterfat, yucca, and white bursage. Joshua tree is scattered across many sites and can be abundant. Cactus species include various prickly pears and chollas as well as hedgehog species. Perennial grasses such as big galleta, bush muhly, black grama, Indian ricegrass, desert needlegrass, dropseeds and perennial threeawns are scattered on the uplands. They increase significantly in the drainages. Mesquite and catclaw are often abundant along drainages with an understory of alkali sacaton, vine mesquite, fourwing saltbush, and shadscale. Wet periods, particularly in the spring, will produce large quantities of annual grasses and forbs.

This resource area occurs in Mohave County, Arizona. Urban areas include Dolan Springs, Meadview, and Kingman. Recreation is a very important use of the area, which includes the Lake Mead National Recreation Area and Grand Canyon National Park.

Cow-calf and stocker livestock operations utilize the area.

Lower Mohave Desert

This resource area occurs within the Basin and Range Physiographic Province and is characterized by broad valley plains, alluvial fans, and hills. Sediments are fluvial, lacustrine, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from about 500 to 2500 feet. Precipitation averages 3 to 6 inches per year. Dominant shrubs on the uplands are creosote bush, white bursage, white ratany, Mormon tea, brittlebush, and buckhorn cholla, barrel cactus, and hedgehog cactus. There are few perennial grasses on the uplands. Big galleta, bush muhly, sand dropseed, and threeawn species occur primarily in along washes. Wet winters can produce a significant crop of annual grasses and forbs which include sixweeks grama, needle



grama, sixweeks fescue, Indian wheat, evening primrose, and lupine. Introduced species such as red brome and filaree are also abundant. On the salt influenced soils along the Colorado River, the plant community is tree and shrub dominated. Mesquite is the dominant tree, and arrowweed is the dominant shrub. Salt Cedar, an introduced species, has become widespread on these saline bottomland soils.

The Colorado River passes through this resource area, providing a narrow band of lush green vegetation in an otherwise very dry desert. The Topock Marsh is an important wildlife area along the Colorado River. Man made lakes in this resource area include Lake Mead and Lake Mohave.

Urban areas in this resource area include Bullhead City, Oatman, Yucca, and Fort Mohave.

Recreational use in this resource area is mostly limited to the cooler winter season. This resource area includes portions of Lake Mead National Recreation Area. Mount Wilson Wilderness, Havasu National Wildlife Refuge, Warm Springs Wilderness, Mount Nutt Wilderness

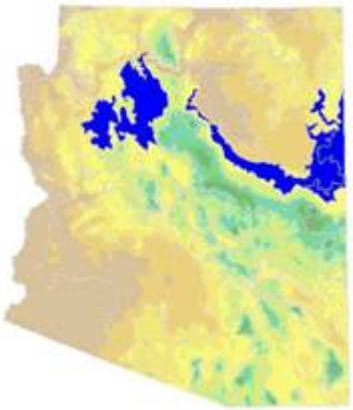
Colorado Plateau

Nine resource areas have been identified in the Colorado Plateau region

Colorado Plateau Grasslands and Pinyon-Juniper Savannahs

This resource area is characterized by a flat to gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 5100 to 6000 feet. Precipitation averages 10 to 14 inches per year.

This resource area supports a perennial grassland dominated by needle grasses, Indian ricegrass, galleta, and blue grama. The drainageways support alkali sacaton, western wheatgrass, and vine mesquite. Scattered shrubs include fourwing saltbush and winterfat. Scattered one-seeded juniper and cliffrose stands occur mostly on shallow soils in the higher rainfall areas.



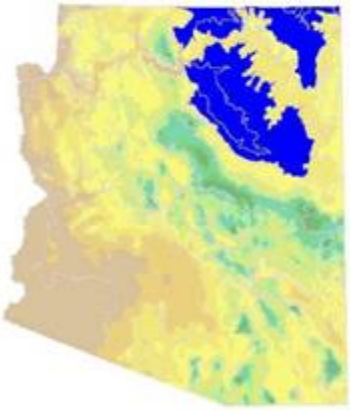
The Little Colorado River runs through this Resource area on it's way to the Colorado River. Other major drainages include Silver Creek, Puerco Creek, Chevelon Creek, Big Chino Wash, Clear Creek and Cottonwood Wash. Few of these drainages have perennial water. Lakes in the area include Stone Lake, Red Lake, Dry Lake, Concho Lake, Becker Lake, Lyman Lake, and Little Ortega Lake. Most of these Lakes do not have a permanent supply of water. Ground water is generally deep and often of poor quality.

Recreation is an important use of this area, which includes Meteor Crater, and the Strawberry Crater Wilderness. This area also includes the Wupatki National Monument, and portions of the Kaibab, Prescott, and Coconino National Forests.

The area is primarily used for livestock grazing by cattle and sheep. The area provides relatively dependable perennial grasses during the growing season. Fourwing saltbush and winterfat provide important browse during the winter. The open and relatively flat aspect of this Resource area makes it well suited for grazing.

Colorado Plateau Cold Desert Shrub - Grasslands

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by a gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 3500-5500 feet. Precipitation averages 6 to 10 inches per year. This is the driest resource area on the Colorado Plateau



Shadscale, fourwing saltbush, and Mormon tea are characteristic shrubs on many sites, while blackbrush dominates others. Grasses such as galleta, blue grama, black grama, and Indian ricegrass can be abundant on some upland sites. Alkali sacaton and vine mesquite are found on the bottom sites.

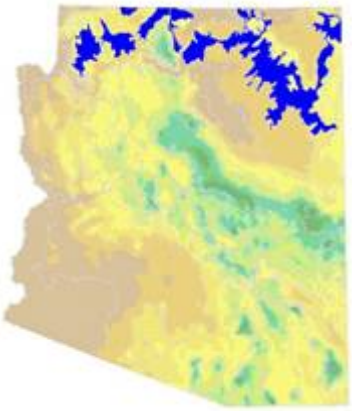
The semi-perennial Little Colorado River runs through this Resource area near it's junction with the Colorado River. Other major drainages include Moenkopi Wash, Chevelon Creek, Clear Creek, and the Puerco River. None of these drainages have reliable perennial water. Ground water is generally deep, with low flows, and often of poor quality.

Recreation includes visits to some of the most spectacular scenery in the state, including Canyon De Chelly, portions of the Grand Canyon National Park, Glenn Canyon National Recreation Area, and Petrified Forest National Park. Visits to the Navajo and Hopi cultural events are also included. This area also includes the Painted Desert, and Monument Valley.

The area is primarily used for livestock grazing by cattle and sheep. The area provides a fair amount of perennial grass. Fourwing saltbush and winterfat provide important browse during the winter months. The open and relatively flat aspect of this Resource area makes it well suited for grazing.

Colorado Plateau Sagebrush – Grasslands

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 4500 to 6000 feet. Precipitation averages 10 to 14 inches. Snow usually lasts for 3-4 days but can persist much longer.



Big sagebrush is characteristic of many sites and can be dominant on some of them. Other shrubs include cliffrose, Mormon teas, fourwing saltbush, and blackbrush. Utah juniper and Colorado pinyon are scattered across many sites and can be numerous on the hills and shallow soils. Most sites will support an abundance of perennial grasses such as blue grama, galleta, squirreltail, Indian ricegrass, and various stipas. Perennial grasses can be dominant on a number of sites.

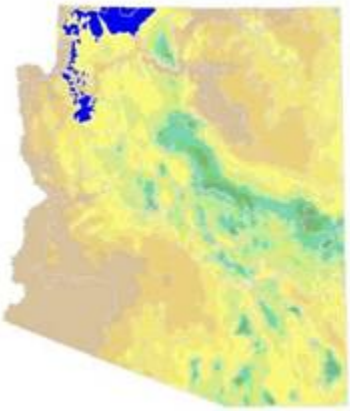
This area has a few man-made lakes. Dirt ponds built for livestock water are often dry due to sporatic rainfall. There are no perennial streams or significant lakes in this Resource area. Major drainages include Kanab Creek and the Paria River. Wells are very deep and widely scattered. Springs are also scarce.

Recreational use includes visits to some of the most spectacular scenery in the state, including Canyon De Chelly, the Grand Canyon National Park, Monument Valley, and the Lake Mead National Recreation Area.. Several wilderness areas are located in this Land Resource Unit where people may camp and backpack. Hunting is another important use of the area. This Resource area includes the Paiute Wilderness, Grand Cliffs Wash Wilderness, Paria Wilderness, Cottonwood Point Wilderness, Kanab Creek Wilderness, Paria Canyon Vermillion Cliffs Wilderness. The area also includes portions of the Grand Canyon National Park, Lake Mead National Recreation Area, Windsor Castle White Springs National Monument, Kaibab National Forest, Monument Valley Navajo Tribal Park, Navajo National Monument, and Canyon De Chelly National Monument.

The area is primarily used for livestock grazing by cattle and sheep. The area produces a reliable stand of perennial grass and browse. Fourwing saltbush and winterfat provide important browse during the winter months. Permanent water supplies for livestock are scarce in many areas.

Colorado Plateau Cold Desert Grasslands

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 4200 to 5100 feet. Precipitation averages 7 to 11 inches. The soil temperature regime is mesic.

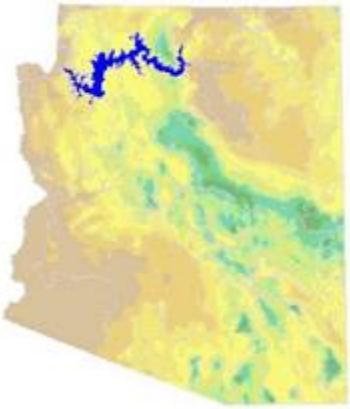


This Resource area is characterized by Wyoming big sagebrush with an understory of mid grasses and short grasses. Utah juniper and Colorado pinyon are scattered across the shallower soils. Indian ricegrass, needle and thread, and western wheatgrass are the dominant cool season grasses. Galleta, black grama, blue grama, and sand dropseed are the major warm season grasses. Winterfat, fourwing saltbush, and Wyoming big sagebrush are the dominant shrubs.

There are no perennial streams or significant lakes in this resource area. Major drainages include Kanab Creek and the Paria River. Springs are also scarce. This area has a few man-made lakes. Dirt ponds built for livestock water are often dry due to sporadic rainfall. Wells are very deep and widely scattered.

Grand Canyon Corridor

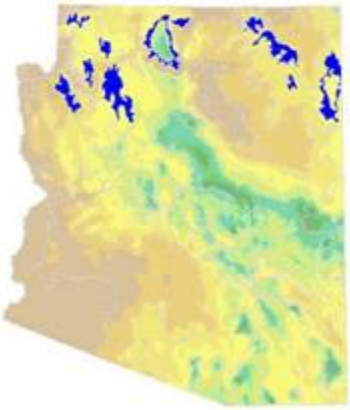
This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by extreme vertical escarpments and strong aspect differences over short distances. Sedimentary rock classes dominate. Elevations range from about 1600 to 4500 feet. Precipitation averages 6 to 10 inches per year.



Vegetation in the riparian zones along the Colorado River and its tributaries includes various willows, arrowweed, and mesquite; also present are common reed and numerous rushes and sedges. Salt Cedar, an introduced species, is now common in the riparian zones. Mormon tea, catclaw, white brittlebush, and various cactus species are characteristic of the sites that contain the hills, cliffs, and steep colluvial slopes. Big galleta, blue threeawn, and a wide variety of forbs are also common. The plant communities on these sites are strongly influenced by the presence or absence of eolian sand deposits on the soil surface. They also reflect the extremes of very hot and relatively cool exposures. Many of the upland sites have a blackbrush component and on some sites it is dominant. Certain upland sites at higher elevations will support a mixed grassland-shrub community.

Colorado Plateau Pinyon-Juniper-Sagebrush

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 5500 to 7000 feet. Precipitation averages 13 to 17 inches per year. Snow is common from November through mid-April.



This resource area has a characteristic overstory of pinyon-juniper, with many sites classified as forestland with the potential of achieving a tree canopy cover greater than 25 percent. Utah juniper and Colorado pinyon are the dominant species, but singleleaf pinyon, Rocky Mountain juniper, and ponderosa pine can be present. Gambel oak can sometimes be found in tree form, although it is usually present as a shrub. Other shrubs include big sagebrush, cliffrose, and Mormon tea. Perennial grasses include muttongrass, prairie junegrass, western wheatgrass, and blue grama. Some sites, especially those with deep soils, are a shrub-grassland community with scattered trees.

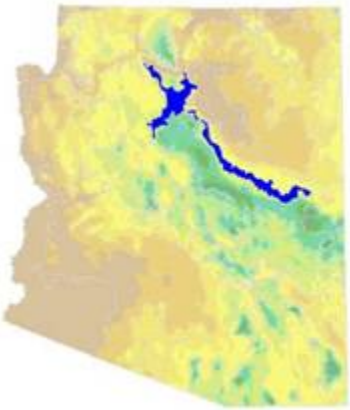
Water is scare throughout this resource area. Stock ponds usually fill with snow melt, but often go dry during the drier summers. There are no perennial streams or significant lakes.

Recreation is a important use of this area. This resource area includes all or portions of the Paiute Wilderness, Mount Logan Wilderness, and Saddle Mountain Wilderness. It also include portions of the Kaibab National Forest, Grand Canyon National Park, and Lake Mead National

Recreation Area. The pinyon - juniper plant communities provide firewood, pinyon nuts, and posts. Most of the resource area is used for livestock grazing by sheep, cattle, and horses.

Colorado Plateau Pinyon - Juniper - Grassland

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevation ranges from about 5000 to 7000 feet. Precipitation averages 14 to 18 inches per year. The maximum snowfall comes from November through March. Snowfall is generally light, and normally only last for a few days.



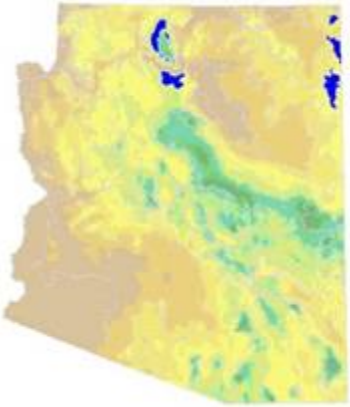
This resource area supports a mixture of forest and grassland plant communities. Approximately 75 percent of the area has a cover of juniper and pinyon, with an understory of forage for livestock and wildlife. The remaining 25 percent is open grassland. Dominant trees include one-seed juniper and Colorado pinyon. Important browse plants include Stansbury cliffrose, apache plume, fourwing saltbush, and green Mormon tea. Important grasses include needlegrass species, blue grama, galleta, sideoats grama, bottlebrush squirreltail, and muttongrass. The bottom-land soils support mostly grasslands of western wheatgrass, vine mesquite, and spike muhly.

Silver Creek, in southern Navajo County, is the only perennial stream. Other rivers include portions of Clear Creek, and Chevelon Creek. Lakes include Dog Knobs Lake, Red Lake, Smoot Lake, Howard Lake, Babbit Lake, JD Dam Lake, Fool Hollow Lake, Long Lake, Little Mormon Lake, White Lake, Ned Lake, Whipple Lake, Ortega Lake, and White Mountain Lake.
In general, groundwater is deep. Stock tanks and windmills provide water for livestock and wildlife.

Recreation is a important use of this Resource area. Hiking and camping occur in and around the Strawberry Wilderness and Alen Severson Memorial Wildlife Area. Portions of the Coconino and Apace-Sitgreaves National Forests also occur within this Resource area.
This resource area is used for sheep and cattle grazing. Wildlife species include elk, black bear, turkey, and white tail deer.

Colorado Plateau Ponderosa Pine Forests

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from 6800 to 8500 feet. Precipitation averages 17 to 25 inches per year.

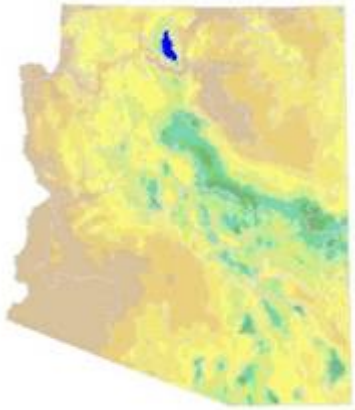


Ponderosa pine dominates most sites. White fir and aspen can be found in some areas, while pinyon and juniper are often present on the warmer exposures. Gambel oak is frequently present in tree form, and occasionally as a shrub. A scattered shrub understory includes big sagebrush, ceanothus, and blue elderberry. Under a heavy tree canopy the herbaceous understory is limited to shade-tolerant perennial grasses such as

muttongrass, upland sedge, and big wildrye, and forbs such as lotus and wood betony. Openings support a diverse grass-forb understory with scattered shrubs. Perennial grass species include mountain muhly, Arizona fescue, pine dropseed, and blue grama. Many species of annual and perennial forbs can be found.

Colorado Plateau Mixed Conifer Forests

This resource area occurs within the Colorado Plateau Physiographic Province and is characterized by gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Volcanic fields occur in places. Elevations range from about 8000 to 9700 feet. Precipitation averages 25 to 33 inches per year.



White fir, ponderosa pine, and quaking aspen are the dominant species on some forest sites. Other, generally cooler, sites have dense stands of Engelmann spruce and subalpine fir mixed with aspen. Douglas fir can be present in both forest communities and is occasionally abundant. Under a dense tree canopy the herbaceous understory is a very sparse mixture of species such as muttongrass, upland sedge, big wildrye, redroot buckwheat, creeping mahonia, and dwarf juniper. Clearings and deep upland soils will support numerous grass species that include mat muhly, mountain muhly, various fescues and stipas, and alpine timothy. These open areas also have a rich diversity of annual and perennial forbs, or wildflowers. Bottom sites are generally confined to drainages and sinks. They contain wetter-loving species such as tufted hairgrass, bentgrass, and several types of rushes and sedges.

Mogollon Transition

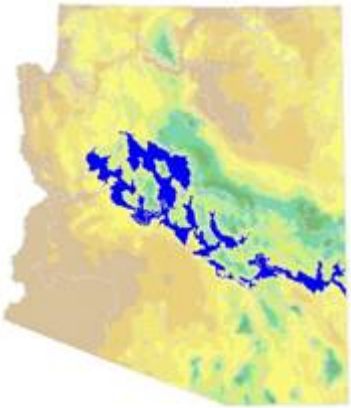
This Major Land Resource Area is divided into three resource areas.

Mogollon Transition Chaparral Grasslands

This unit is characterized by canyons and structural troughs or valleys. Mountainous areas are interrupted by grassy mesas and dissected by deep rough canyons. Igneous, metamorphic and sedimentary rock occur on the mountainous terrain. Elevations range from 3000 to 4500 feet. Precipitation averages 12 to 16 inches per year. Snow seldom persists more than a day.

Deep, heavy textured uplands are open grasslands dominated by tobosa, vine mesquite, and bottlebrush squirreltail. Deep and moderately deep loamy soils are dominated by grama species, curly mesquite, squirreltail, and shrubs like jojoba, mesquite, blue paloverde, algerita, skunkbush, and scattered turbinella oak. Shallow soils on hill slopes are diverse grass, shrub, and tree mixtures. The major grasses include desert stipa; New Mexico feathergrass; black, hairy, sideoats, and slender gramas; tobosa, curly mesquite, squirreltail; and red and blue threeawns. The common trees include canotia, one-seed juniper, mesquite, catclaw acacia, and blue paloverde. Important shrubs include jojoba, ratany, shrub buckwheat, algerita, skunkbush, and

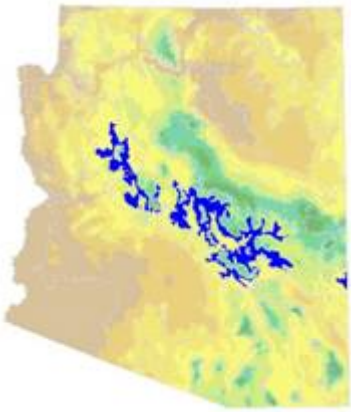
shrub penstemon. This zone is a mixture of transition from Upper Sonoran to Interior Chaparral vegetation and as such it is not uncommon to see species like saguaro and juniper together on steep southern exposures. Riparian bottoms support Fremont and narrowleaf cottonwood, Gooding's and coyote willow, Arizona sycamore, Arizona blackwalnut, Arizona ash, thinleaf alder, maple and netleaf hackberry.



There are few live streams in this area. Ground water is deep and not in any abundance. A few windmills furnish water for livestock and game animals. Some water tanks are scattered throughout the area. Livestock grazing occurs over most of this resource area. Chaparral areas are used locally for harvests of fuelwood, craft woods, acorns, mistletoe, and Christmas trees.

Mogollon Transition Pinyon – Juniper - Chaparral

This unit occurs within the Transition Zone Physiographic Province and is characterized by canyons and structural troughs or valleys. Igneous, metamorphic and sedimentary rock occurs on rough mountainous terrain. Elevations range from 4000 to 5500 feet. Precipitation averages 16 to 20 inches per year. Snow can accumulate and persist for periods up to 20 days.



This is the well-developed interior chaparral zone where nearly continuous stands of low evergreen shrubs occur on specific hillsites. Cover varies but mature stands average 60 to 70% with virtually no herbaceous species underneath. In this resource area, deep, heavy textured uplands are open grasslands dominated by blue grama, curly mesquite, vine mesquite, prairie junegrass, and bottlebrush squirreltail. Shallow soils over deeply (15-30 ft.) weathered bedrock (grus) are shrublands. These are the chaparral sites in this unit. Turbinella oak is the dominant species. Other important shrubs on these sites include yellowleaf silktassel, hollyleaf buckthorn, desert buckbrush, mountain mahogany, skunkbush sumac, algerita, Palmer's oak, Lowell's ash, pointleaf and Pringle's manzanita, sacahuista, and wait-a-bit bush. Associated trees include one-seed and alligator juniper, pinyon, Arizona white and Emory oak, Mexican mulberry, Arizona cypress, and sugar sumac. These are considered range sites as the dominant species are shrubby and have little value for wood products. Shallow soils over hard bedrock (basalt, quartzite, etc.) have diverse plant communities of perennial grasses and forbs, shrubs, and scattered trees. major grasses include the gramas, prairie junegrass, muttongrass, can beardgrass, plains lovegrass, and bullgrass. Common shrubs include the chaparral species mentioned above plus shrubby buckwheat, range ratany, whiteball acacia, sticky selloa, bastard toadflax, fendlerella, cliff fendlerbush, and bundleflower. Important perennial forbs include herbaceous sage, Colorado four o'clock, rock cress, shrubby deervetch Indian paintbrush, vetch, breadroot, cutleaf, pink perezia, groundsels, and locoweeds. Riparian bottoms support Fremont and narrowleaf cottonwood, Gooding's and coyote willow, Arizona sycamore, Arizona blackwalnut, Arizona ash, thinleaf alder, maple and netleaf hackberry.

Historically naturally occurring wildfires played an important role in the interior chaparral communities. Fires in dense stands of the characteristic species, only temporarily open them. Most species sprout rapidly from the massive root crowns after fire. Some have fire-adapted

seeds which may be stored in the soils for decades and germinate readily only after fire. Dominant species like turbinella oak usually recover to nearly preburn canopy cover in 10-11 years.13 Fire-free intervals in the Arizona chaparral may be quite long, up to 100 years, allowing communities to shift towards non-adapted species like one-seed juniper, pinyon, Arizona white oak, and Arizona cypress at the end of the interval only to go back to chaparral after fire.

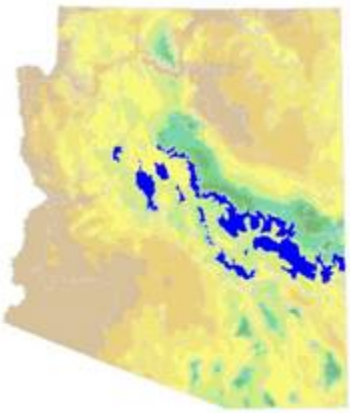
Wildlife include black bear, mule deer, Coues' whitetail deer, antelope, desert bighorn sheep, javelina, and mountain lion. This resource are has the highest densities of black bear in the state. Small game include Gambel's and scaled quail, rabbits, mourning and white wing dove, and bandtailed pigeon. Migratory water fowl like mallard, geese, gadwall, canvasback pintail and teal winter on small lakes and ponds in the area.

In the mixed forest zone of this Resource area, alligator juniper has thickened tremendously on moderately deep and deep loamy soils, which were once open grasslands or juniper - grass savannah. Historically, wildfires every 10 to 30 years restricted juniper woodlands to shallow, rocky sites with rough topography. Active fire suppression and grazing domestic livestock both contributed to the rapid encroachment of juniper. Present day use of both prescribed burning and wood cutting can help restore these unnatural stands to something which more resembles the potential plant communities

Non-consumptive uses of wildlife like bird-watching and photography are becoming increasingly popular. Fishing in many streams, rivers and lakes in this unit provide opportunities for both cold and warm water game species. Livestock grazing is still practiced over most of this unit. These areas can be grazed throughout the year. This resource area was utilized extensively by goats during WWII. A few small goat operations have started up in recent years in the better chaparral areas. The potential for large scale utilization is limited by fencing costs, and the high density of predators in these areas. Areas are used locally for harvests of fuelwood, craft woods, acorns, mistletoe, and Christmas trees.

Mogollon Transition Oak Pine Forests

This unit occurs within the Transition Zone Physiographic Province and is characterized by canyons and structural troughs or valleys. Igneous, metamorphic and sedimentary rock occurs on rough mountainous terrain. Elevations range from 5100-7000 feet. Precipitation averages 20 to 27 inches per year. Snow can persist for months at the highest elevations.



Vegetation includes Gambel oak, Arizona white oak, Emory oak, pinyon, juniper, Arizona cypress, and ponderosa pine. Emory and Arizona white oak mix with alligator juniper, pinyon pine, and singleleaf pinyon in a cold adapted evergreen woodland with enough summer rain and mild enough temperatures for the Mexican liveoaks to flourish. It is here, below the Mogollon Rim, where singleleaf pinyon (P. monophylla) was forced northward by the warming trend that followed the last ice age, and encountered pinyon pine (P. edulis) outliers from the Colorado Plateau. Where they meet in this Resource area, hybridization has occurred. These characteristics distinguish these forests from those on the Colorado Plateau north of the Mogollon Rim. Higher elevation forests are dominated by ponderosa pine. Important shrubs in the understories include New Mexico locust, flame sumac, Fendler buckbrush, creeping mahonia, wild

currant, wild rose, and snowberry. Important perennial grasses include mountain muhly, nodding brome, muttongrass, Arizona fescue, sideoats grama, western wheatgrass, blue grama, prairie junegrass, bottlebrush squirreltail, Canada bluegrass, and sedge. This upper zone has some of the highest site indexes for ponderosa pine in the state, due to high rainfall and warmer temperatures.

Historically, naturally occurring wildfires played an important role in shaping the forests in this resource area. Tree ring research has reconstructed wildfire histories for the past 300 year in central Arizona and New Mexico pine forests. Fire frequencies in the ponderosa pine forest range from 7 to 10 years on moderately deep soils on gentle slopes, to 20 to 30 years on shallow soils with steep slopes. These forests on level slopes were open and had understories of forbs and grasses which made such stands valuable for large herbivores like elk and cattle. Present day stands are unnaturally thick and unproductive. Doghairs of 2000 to 9000 stems per acre are not uncommon. Manual thinning began in the late 1950s and has continued on a small scale to the present day, opening stands to allow for more productive understory vegetation, more productive trees, and reduced fire hazards.

The mountainous watersheds of this unit provide much of the runoff to Salt and Verde Rivers to supply the reservoirs of the Salt River Project, the lifeblood of the Phoenix basin. They also provide some of the runoff to the Gila River system and San Carlos reservoir. The major rivers running through this unit include the Salt, Verde, Agua Fria, Hassayampa, Santa Maria, and Burro Creek with major tributaries including San Carlos Creek, Blue Creek, Eagle Creek, Canyon Creek, Cherry Creek, Salome Creek, Tonto Creek, Fossil Creek, and Walnut Creek.

Wildlife uses are also very important. Species include mule deer, Coues whitetail deer, pronghorn antelope, elk, javelina, turkey, black bear, and mountain lion. Water fowl include Canadian and snow geese, mallard, pintail, gadwall, canvas back, and teal. These water fowl winter on ponds and small lakes in the area. Other wildlife includes rabbits, tree squirrels, bandtailed pigeon, whitewing dove, and mourning dove. Fishing in the numerous small streams, lakes, and ponds throughout the area provide put and take opportunities for cold water species, including two species of native trout. Nonconsumptive uses of wildlife, including bird watching and photography, are becoming increasingly popular.

Rangeland and most forestlands in this resource area are grazed throughout the year by cattle. Most forest lands are grazed seasonally in the spring and summer. Most ranchers practice some form of grazing rotation to maintain healthy rangelands. Forests are utilized for wood products like poles, lumber, pulpwood and firewood.

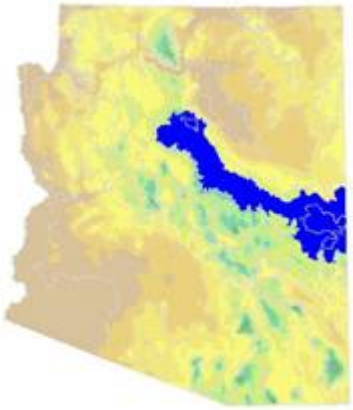
Mogollon Coniferous Forests

Mogollon Plateau Ponderosa and Mixed Conifer Forests

This unit occurs within the Colorado Plateau Physiographic Province and is characterized by volcanic fields and gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Steep, low hills formed by cinder cones are scattered throughout the area. Elevations range from 7000 to 12,500 feet. Precipitation averages 20 to 35 inches per year. Snow cover may remain on the ground from November through April, and at the highest elevations, even through June.

Important trees include Gambel oak, Arizona walnut, sycamore, aspen, Douglas fir, and blue spruce. Important understory grasses include Arizona and sheep fescue, mountain and screwleaf muhly, junegrass, muttongrass, pine dropseed and dryland sedges. Wet and dry meadows,

dominated by redtop, hairgrass, bluegrass, rushes, sedges, willows, wild rose, cinquefoil and numerous forbs are scattered throughout the area.



Numerous live streams headwater in this resource area, including the White River, Black River, and the Little Colorado River. Other Rivers include East Clear Creek, Oak Creek, Chevelon Creek, Tonto Creek, Showlow Creek, and Beaver Creek. Lakes include White Horse Lake, Dogtown Reservoir, Cataract Lake, Kaibab Lake, Duck Lake, Coleman Lake, Mormon Lake, Lake Mary, Roper Lake, Marshall Lake, Vail Lake, Ashurst Lake, Long Lake, Blue Ridge Reservoir, Stoneman Lake, Woods Canyon Lake, Scott Reservoir, Rainbow Lake, Hawley Lake, Big Lake, and many others.

Groundwater is deep, but of generally good quality in this resource area. Groundwater, springs, and stock ponds provide water to livestock and wildlife.

Recreation is a important use of this Resource area. Hiking and camping occur in and around the Paiute Wilderness, Saddle Mountain Wilderness, Kachina Peaks Wilderness, Kendricks Peak Wilderness, Strawberry Wilderness, Woodchute Wilderness, West Clear Creek Wilderness, Mount Baldy Wilderness, Escudilla Mountain Wilderness, Blue Range Primitive Area and Bear Wallow Wilderness. This Resource area also include portions of the Kaibab National Forest, Grand Canyon National Park, Sunset Crater Volcano National Monument, Coconino National Forest, Prescott National Forest, Apache – Sitgreaves National Forest, Tonto Creek Recreation Area, and Walnut Canyon National Monument. A significant amount of water based recreation occurs on the numerous lakes and rivers in this Land Resource Area.

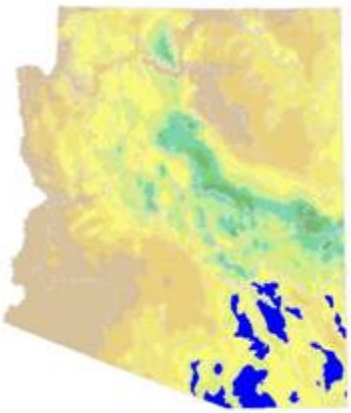
Important wildlife species include elk and white tail deer. Cattle grazing occurs on a significant portion of this Resource area. Grazing on many areas, especially at higher elevations, occurs only during the summer months.

Madrean Basin and Range

This region has been divided into three resource areas

Mexican Oak-Pine Forest and Oak Savannah

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from 4500 to 10,700 feet. Precipitation ranges from 16 to 30 inches.



The lowest precipitation zone with 16 to 20 inches mean annual precipitation occurs at elevations from 4500 feet on north exposures to 6500 feet on southern ones. The potential natural vegetation here is oak - Savannah with open canopies (5-10%) of Emory, Mexican blue, Arizona white oak, and one seed juniper and perennial grasses in the understory. The major grasses include sideoats, blue, hairy and purple gramas, bullgrass, deergrass, Texas bluestem, plains lovegrass, woolly bunchgrass, crinkleawn, prairie junegrass, squirreltail, pinyon ricegrass, and beggartick threeawn. The dominant shrubs are sacahuista, California bricklebush, wait-a-bit mimosa, and yerba de pasmo. Average annual production of these grasslands is

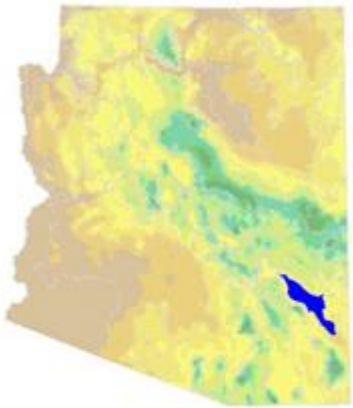
about 1500 pounds per acre.

Above 20 inches mean precipitation, woodlands are the potential. In the 20-27 inch precipitation zone, at elevations from 5500 feet on northern aspects up to 7500 feet on southern ones, the woodland is dominate by evergreen live oak, juniper and pinyon. The dominant trees include Arizona white, Emory, and silverleaf oaks, alligator juniper, and Mexican pinyon. Associated shrubs are manzanita, mountain mahogany, silktassel, skunk bush sumac, sacahuista, Arizona rosewood, macrosiphonia, and bundleflower. Important grasses are sideoats grama, plains lovegrass, pinyon ricegrass, muttongrass, prairie junegrass, and bullgrass.

There are no perennial streams in this unit. Streams flow during the spring snow melt and following heavy summer rains. There are a few small man-made lakes in the area which are used exclusively for recreation. Except for a short period during the spring snow melt period, groundwater is deep and in very short supply. The mountainous watersheds of this resource unit area provide municipal and domestic water for several communities in adjacent areas. Examples include Safford using water from the Pinalenos and Gila Mountains and Tombstone and Fort Huachuca using water from the Huachuca Mountains.

Chihuahuan – Sonoran Desert Shrubs

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from 2600 to 4000 feet. Precipitation ranges from 8 to 12 inches per year.



Potential plant communities in this resource unit are dominated by desert shrubs and trees with sparse covers of perennial grasses. The major perennial grasses are tobosa, black grama, purple and blue threeawns, bush muhly, sand, spike, and mesa dropseed, and burrograss. Sonoran desert shrubs mix with Chihuahuan species. The major trees include mesquite, catclaw acacia, canotia, and palo verde. Dominant shrubs include soaptree yucca, creosote bush, whitethorn acacia, rayless goldenhead, mariola, staghorn cholla, desert saltbush, shortleaf baccharis, Mormon tea, burroweed, snakeweed, and jimmyweed. Average annual production of these shrub lands is about 600 pounds per acre.

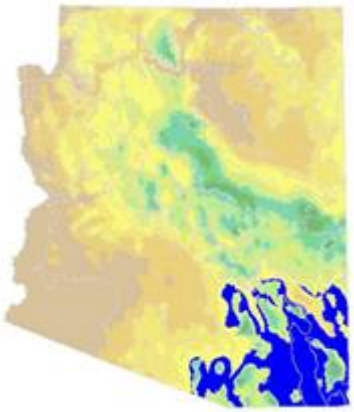
Wildlife species include javelina, desert mule deer, Gambel's quail, mourning and whitewing dove, jack rabbits, and cottontail. San Carlos Reservoir on the Gila River provides some of the best water fishing opportunities in this part of Arizona, as well as winter habitat for migratory waterfowl.

The Gila River flows through the northern segment of this resource area and is a perennial stream. There are no other perennial streams. There are no lakes or reservoirs. In the vicinity of San Simon, ground water from deep wells is pumped to obtain water for irrigating a relatively small area. Water is generally scarce. The drainage patter is well developed. Both the Gila and the San Simon have networks of prominent tributaries. Coolidge Dam on the Gila and two large structures on the San Simon (Fan, Barrier) provide base level control for the watersheds in this unit.

Nearly all of this area is grazed by livestock. Animal numbers fluctuate widely between years with favorable moisture and drought years. The water supply for wildlife and livestock in this resource area is mostly from pumped underground supplies. Although there are some stock ponds in this resource area, the low annual rainfall makes them unreliable unless they are very large, and capture water from large watersheds or they are located adjacent to bedrock slopes that produce higher runoff during storm events.

Chihuahuan – Sonoran Semidesert Grasslands

This resource area is characterized by valley plains, alluvial fans, and hills. Sediments are fluvial, colluvial and alluvial deposits. Igneous and metamorphic rock dominate the hills. Elevations range from 3200 to 5000 feet. Precipitation ranges from 12 to 16 inches per year. Vegetation includes sideoats grama, black grama, plains lovegrass, and tobosa.



Sonoran desert influences on the west side of this resource area result in the occurrence of shrubs like jojoba, blue palo verde, staghorn and jumping cholla, and fishhook barrel cactus in the plant communities. Chihuahuan desert influences on the east side of the resource area result in the occurrence of shrubs like mariola, mortonia, chittam, tarbush, whitethorn acacia, and littleleaf sumac in the plant communities. Wildlife species include javelina, desert mule deer, pronghorn antelope, Coues whitetail deer, and desert bighorn sheep. Other wildlife species include Gambel's and scaled quail, mourning dove, cottontail, and jack rabbits. Over 12,000 sandhill cranes winter in the Willcox Playa and the cienegas in the Sulphur Springs Valley.

The San Pedro and Santa Cruz Rivers run through the central and western portions of this resource area. The San Pedro is a live stream for some distance after it enters the United States from Mexico. The Santa Cruz River is an intermittent stream. Sufficient groundwater is present along the lower portions of the larger valleys to permit pumping for irrigation water. Water in general is scarce. The drainage pattern is well developed throughout the area. The flood plains are narrow ranging in width from 1/2 to 2 miles. The old dissected fans are extensive, making up the remaining 10 to 20 miles between mountain ranges. A closed drainage system occurs around the Willcox Playa with numerous small streams spreading out on the alluvial fans flanking the lake bed. Major streams, like the Santa Cruz, San Pedro, Whitewater Draw, and Black Draw, pass through this resource unit, and have well developed tributaries.

Nearly all of this resource unit is grazed throughout the year by livestock. Cow-calf operations are the most common commercial operations. There are also a few horse and other livestock operations. Water for livestock and wildlife is provided by a combination of wells, springs, and stock ponds. Most ranches depend to some extent on capturing water in stock ponds to adequately distribute and rotate livestock grazing through pastures that are established for grazing management. The lack of rainfall and runoff into stock ponds during drought often limits the ability of ranches to utilize all of the available forage on the ranch. This forces livestock, and to some extent wildlife, to concentrate around more the more permanent and reliable water sources during drought periods.

III. DROUGHT IMPACTS

Because of the variety of Arizona's topography, the average annual temperature and precipitation vary widely. Statewide the variation in precipitation ranges between 3 inches to 30 inches. The state can be divided into three distinct climatic zones. The arid Sonoran Desert is hot in summer but experiences frost in most winters. Most of the Sonoran Desert receives less than about 8 inches of precipitation each year. The Colorado Plateau region is hot and relatively dry in summer and windy and cold in winter. In most parts of the region annual precipitation is less than 16 inches. The Mexican Highland region receives significant precipitation in both the summer and the winter, and yearly precipitation in lofty sections can reach about 30 inches. Temperatures in summer are appreciably lower than in the Sonoran Desert, and temperatures on winter nights are generally below freezing (0° C/32° F). Drought has long been part of Arizona's climate throughout these zones. In order to develop a monitoring network that is beneficial to water users in these sectors, it is first important to understand the impacts of drought on these systems.

Drought impacts much more than our environment. Economic and social structures have also seen profound affects. Much legislation has come in response to drought, which in turn has lead to changes in management strategies. Drought is not the only factor involved though. Major cities along with many other communities across the Southwest are experiencing a disproportionate increase in population. The result is an increase in demand for resources. This has been mitigated somewhat by controlling rivers through reservoirs and trans-basin projects.

Watersheds

Drought leads to plant and animal population declines, loss of habitat, changes in water quality, movement within catchments, and crowding of fish in reduced habitats. Although most species recover quickly from drought, those that are vulnerable have probably already disappeared from some basins before the mid 1900's (Matthews and Marsh-Matthews 2003). Drought affects the levels of organization of fish on all scales. The hardest hit species though are those that require high flow for reproduction (Parker and Wooton, 1995).

Douglas et. al. (?) discovered a basin wide crash in the Flannelmouth sucker in the Colorado River Basin. A period of extreme drought was responsible for a large number of extinctions. Although the Flannelmouth sucker was able to survive this drought, it did experience a population bottleneck and yet over time was able to repopulate the entire basin. The ability of this species to survive and repopulate may have occurred numerous times throughout other drought events, yet it is uncertain if this phenomenon could occur today due to the development of dams and reservoirs and the changes to the structure and function of these habitats.

Riparian and aquatic ecosystems are important indicators of the health and integrity of a river basin in that they integrate and respond to all of the external processes and perturbations occurring in the watershed (Patten, et. al). Surface water is usually the most visible indicator of drought on the watershed. Water levels drop in lakes and other bodies of water. Streamflow declines, sometimes causing loss of connectivity. Water stagnates which leads to decreased water quality. Obviously, these symptoms can have profound effects, causing not only dramatic population reductions in freshwater systems, but may also "induce a breakdown in behavioral hierarchies of fishes, increase parasite loads, and sever gene flow among populations thereby reducing genetic variability"(Douglas et. al.).

Riparian forest vegetation throughout much of Arizona relies on seasonal floods to complete their lifecycles. Stromberg (2003) analyzed tree cores from several reaches of Sycamore Creek along with historical climate data and found that the volume of flow in the stream, which can also infer water availability, was found to directly influence vegetative growth rates, specifically limiting

growth during drought – or low flow - periods. Sycamore Creek is dependent on winter floods to recharge the shallow alluvial aquifer and raise levels of groundwater to within the root zone. It was also suggested that the summer floods stimulate growth by replenishing nutrients, especially nitrogen.

Watersheds contain the plant communities that provide necessary forage for many wildlife and domestic animals. Water stress, according to Howery (2000), affects physiological and biochemical processes of plants – reducing photosynthesis and thus slowing the growth of the plant. When shoot growth is limited, carbohydrates may not be available to replace root die-off. Further, some grasses may be so stressed that they do not put out seed heads, disrupting the regeneration of these plants. During drought there may also be fewer plants per unit area. Herbel et. al. (1972) found black grama cover reduced to such a low level in response to the drought of the 1950's that on several soil types it was unable to recover in subsequent years. With the absence of ground cover, wind erosion stripped much of the land and many of the remaining plants were killed as a result of sand deposition. "Some ranges had been swept clean in 1917" (Arizona Republic *quoted from* Hasemeier 1977). This bare ground "promoted an increase in dust, a problem that intensifies the annual dust storms of Arizona" (Hasemeier 1977). "This happened in the Casa Grande region, causing a very dangerous dust problem to the soil and to highway motorists during dust storms. This condition has caused serious injury and deaths on some of Arizona's highways"(ADOT 1975, *quoted from* Hasemeier 1977).

The droughts of the 40's and 50's had a significant impact on vegetation dynamics. The lower Gila Valley saw a die-off of mesquite thickets as the water table fell and salts accumulated (Hasemeier 1977). Grasses, mesquite, cacti, and conifers suffered broad scale mortality. In some areas, these dieoffs contributed to shifts in ecotonal boundaries along moisture (elevational) and edaphic gradients"(Swetnam and Betancourt ?, Journal of Climate). There was broadscale recruitment of woody species. The invasion of woody plants further contributed to soil erosion, a decrease in grasses, and therefore seed production of which many animals rely on for food (Brown et. al. 1997).

Barton (1993) investigated factors controlling distributional limits in three pine species in the Chiricahua Mountains of Southeastern Arizona. Based on his investigation, it was suggested that water stress controlled the lower elevation extent of all three species. However, Barton also suggested a "trade off between tolerance of light limitation and tolerance of water limitation. Light limitation typically means higher levels of soil moisture. Dry season water stress controlled lower elevation limit by causing high mortality of seedlings rather by hindering seed germination. The results also suggest fire as a direct agent of selective mortality. With an increase in elevation there is increase in the probability of fire as well plant fire tolerance"(Barton 1993).

Fire management practices also play a key role in the vulnerability of a watershed to the impacts of drought and are an important tool in watershed management. "Fire suppression has been partly responsible for rapid conversion of grasslands to shrub lands in Arizona and New Mexico. The encroachment of woody species leads to increased soil erosion, decrease in grasses and therefore seed production which many animals rely for food" (Brown et. al. 1997). "With fire exclusion, dead fuels accumulate continuously, and dense thickets of suppressed trees invade open stands of ponderosa pine. Near continuous fuels from understory to canopy produce the laddering effect commonly seen in catastrophic crown fires. Fire regimes have shifted in Ponderosa pine forests from frequent (2-10 yr intervals) to stand replacing fires" (Swetnam and Betancourt 1990).

There are obviously correlations between drought and fire. A lull in recruitment of seedlings has been found in forest communities, however, White (1976) found that moisture and heat stressed plants have a higher food quality than non-stressed plants. This may have lead to insect (beetle) outbreaks, which have corresponded with historic drought events. "Drought also inhibits the resin production that defends a tree against cambium feeders. Bark beetles were associated with broad-scale tree mortality during the 1986-92 drought in the Sierra Nevadas." These insect

outbreaks also increase the flammable fuel loads in effected communities. Based on the examination of 63 fire scar chronologies from 25 mountain ranges during the last 400 years, Swetnam and Betancourt found that the correlation between drought and fire involves a lag with antecedent soil moisture conditions and furthermore found that a "strong link exists between long time fire suppression, a shift in climate, and increases in total annual area burned for Canada and the Southwest United States. Tree death may occur with extensive rootlet mortality, diminished water transport, and prolonged xylem cavitation during droughts." It was also noted that climate may also be causing an increase in the invasions of exotic plants in the Southwest. "Wetter winters since 1976 have encouraged the spread of red brome, a winter annual, in the upper Sonoran desert of central and southern Arizona. Fuel loads are now far out of equilibrium with natural fire regimes, compounding the effects of the occasional drought. Large fires may actually be stimulated by sequences of extreme wet seasons followed by average or drier than average seasons" (Swetnam and Betancourt, Journal of Climate).

Research has also been conducted on climatic events such as the warm El Nino and the cold La Nina, which were compared to fire statistics for a 300-year period of record. Based on these studies it was found the generally lightning fires begin in the spring and peak in late June to early July and decrease as the summer rainy season progresses. Comparing the fire statistics to the climate events it was determined that small areas burn after wet springs associated with the low phase of the Southern Oscillation, whereas large areas burn after dry springs associated with the high phase of the Southern Oscillation. "Synchrony of fire free and severe fire years across diverse southwestern forests implies that climate forces fire regimes on a subcontinental scale; it also underscores the importance of exogenous factors in ecosystem dynamics." (Swetnam and Betancourt 1990).

Wildlife

Although some species of wildlife found in Arizona have adapted to reduced water supply conditions – most are impacted in some way to persistent drought conditions. Drought impacts to wildlife include a reduction in forage and prey available for food, with less food available supporting young is difficult if not impossible, reduced availability of food can result in malnutrition, increased vulnerability to disease, and termination of pregnancies. Because drought impacts the vegetation, there is less cover to hide in, resulting in an increased threat of predation. Drought obviously results in a general lack of water for those animals that depend not only on water to drink but those that require free flowing water for habitat. In the arid southwest, rain in the winter means that annual plants will be produced in the spring. Many animals key their reproduction to the "green-up" of spring vegetation - a dry winter results in reduced vegetation and few young are produced. Furthermore, drought creates conflicts for habitat and water supplies between wildlife and livestock as well as increases in human-wildlife interactions within the urban areas of the State. These human-wildlife interactions are increased as urban areas expand and wildlife corridors are disrupted.

The Arizona Game & Fish Department manages several game, non-game, and aquatic species in the State of Arizona and has indicated the effects of the recent droughts on many key species. Especially hard hit is Arizona's Sonoran Pronghorn (*Antilocapra americana americana*) population, a species that is already listed as endangered. The Pronghorn have "suffered a significant decline in recent years, as survey estimates dropped from 12,000 in 1987 to 8,000 by 2000" (Arizona Game and Fish Department). Dubay (2002) found that pronghorn antelope receive sufficient water through forbs and other forage species during most of the year. Pronghorn seek free water, however, when enough forbs are not present and probably during lactation. Therefore, during periods of drought, pronghorn densities were higher in areas that contained free water as opposed to those without. Pronghorn so use man-made sources for water, however, pH and dissolved solids were found to influence the use of these water sources.

Drought may also create indirect impacts on certain species. Research being conducted by the Arizona Game and Fish Department is illustrating that predation may increase during drought periods. At the 602-acre Walnut Canyon Enclosure in the 3-Bar Wildlife Area, located in the Tonto National Forest, the prevailing belief that habitat conditions and resource availability are the limiting factors is being proved wrong. The enclosure is nearly one square-mile. "We have had a decade-long drought with an exclamation point in 2002, yet deer numbers, densities, and fawn reproduction have remained as high as during the wet years. Outside the enclosure during the drought, fawn survival rates and mule deer populations have plunged to the lowest numbers in the past half-century. The absence of predation is the only variable that has changed." (Jim DeVos, Arizona Game and Fish Department, 2004). Although deer populations within the enclosures in the 3-Bar Study showed no significant declines, drought combined with increased predation, as suggested by the study, resulted in recommendations for record-low deer hunt-permit levels in 2003 as a result of poor fawn survival in most game units.

Research has also illustrated negative impacts to bird and aquatic populations. Bock and Bock (1999) found drought to have a negative impact on many populations of ground foraging, seed eating birds in the grassland-oak savanna of southeastern Arizona. Drought triggered a loss of food and cover, as grass height, basal area, canopy, and reproductive canopy all declined. Aquatic animals are probably the most vulnerable to drought due to loss of habitat. For example, in 1977 releases from Lake Powell were curtailed due to drought conditions, as a result bass spawning at Lake Mead declined significantly. Optimal bass spawning conditions require a stable or slowly rising water surface, however, as a result of drought conditions, the conditions necessary for bass spawning did not occurred in that year. (Hasemeier 1977).

Another impact of drought that receives significant media attention is increased wildlife-human encounters– especially in urban-wildlife fringe areas. "The urban-wildlife fringe areas often have wildlife densities surpassing those in the adjacent wild lands – even when desert habitat conditions are normal. The adjacent desert habitats are in poor condition now, so our oasis-like urban environments are even more inviting to wild animals," says Urban Wildlife Specialist Joe Yarchin (Wildlife Views, February 3, 2003, Volume 51, No. 5). In 2004, CLIMAS issued a report, authored by Susan L. Simpson, especially for the Governor's Drought task Force (available on the GDTF web site) titled *"Impacts of Drought on Arizona's wildlife and increasing urban human-wildlife conflicts."* Simpson found that the factors that increase stress among wildlife can be generalized under two categories: ecological stress due to climate fluctuation, and habitat stress due to human alteration of the landscape. Often these factors overlap. As drought persists human alterations of the landscape constrain the ability of many animals to migrate to areas where forage and prey are available. Oftentimes this leads to undesirable interaction between animals and humans. Simpson (2004) also found that in comparing the seasonal precipitation with reported 'conflicts' in the Tucson area that wildlife-human interactions increased with the decrease in winter precipitation. Large-scale wildfires, which have increased as a result of long-term fire suppression combined with drought, also influence wildlife-human interactions. According to the Arizona Game and Fish Department, wildfires could result in increased wildlife traffic into some urban areas. For a short time after a fire, animals might have less food and clean water available to them, so they tend to move into areas where they can get those things. Urban areas provide lawns, pet food, birdbaths, fruit trees and ornamental plants.

Wildlife may also negatively impact habitat during drought. A prevailing wildlife biological belief is that deer numbers can reach a density at which they will negatively impact the vegetation, such as on the Kaibab Plateau during the 1930s. A browse line (as tall as a deer can reach and eat standing on its hind legs) can still be discerned today on the Kaibab in northern Arizona (Arizona Game and Fish).

Wildlife in Arizona also provides important economic resources to the State of Arizona. Over 70 percent of the funding for the Arizona Game and Fish Department comes from hunters and fishermen. Silberman (2002) reported a total of all fishing and hunting expenditures in 2001 at

$958 Million. A total of 17,190 full-time or part-time jobs accounted for $314 Million of those expenditures while the state tax revenues totaled $58.2 Million. However, drought can negatively impact these resources. In 2003, the Arizona Game and Fish Department is recommended the commission set the deer permit-tag level for the general deer seasons at 37,025, which is a 4,620-permit reduction from the previous year as a result of drought and poor fawn survival in most game units. In 1977, "as a result of low streamflow," fishing as well as the fishery stocking rates were considerably reduced compared to previous years. Some lakes and streams, including those around Flagstaff, were so low that they were unable to stock them at all (Hasemeier 1977). Not only does drought reduce revenues from hunting and fishing, but drought can also increase expenditures to assist wildlife. During 2002 alone, over 1.2 million gallons of water was hauled in order to offset the impacts of drought on wildlife. The water was hauled into wildlife catchments as early as January. The costs of hauling water is high and wildlife conservation organizations together donated over $60,000 to help the Arizona Game and Fish Department with the task (AGFD 2002).

Livestock

Just as with wildlife, range livestock are dependent on the amount of forage and water available in a particular area. Drought can negatively impact not only the availability of forage, but also the nutrients contained in the forage, which in turn impacts the health of livestock. In response to 2002 drought conditions forage losses across the state of Arizona ranged from 15% to 99%. The Natural Resources Conservation Service (2002) reported forage losses for each of the six Major Land Resource Areas in Arizona based on data from 34 locations statewide. The Mohave Desert (98%) suffered the worst loss, followed by the Colorado Plateau (86%), Mogollon Coniferous Forests (86%), Sonoran Desert (76%), Interior Chaparral Transition (72%), and Southeastern Basin and Range (64%). In 1997, the University of Arizona sampled 11 ranching operations in Southeastern Arizona. Respondents reported that drought in that area had resulted in the deterioration of range conditions, defoliation of mesquite trees, and a diminishing store of water in earthen dams. Additionally, it was reported that livestock suffered losses in market weight, which combined with a downturn in cattle prices resulted in almost a 50 percent decrease in income per head. Respondents also reported a delay in breeding in 1996 and in many cases cows did not produce calves at all. "Many cattle died in drought, several reservations where hit particularly hard. Many ranchers responded by culling herds. Leasers were often mandated by forest Service to destock. Some of the ranchers ultimately liquidated their herds." (Eakin and Liverman).

Range productivity can be significantly impacted during drought. Drought conditions can reduce the availability of good quality forage. Poor quality forage can reduce the viability of a fetus and the health of already stressed cows diminishes. Calves are particularly affected by range conditions, especially in the first six months of development. (Conely, et. al. 1999) Drought can cause the reduction in weaning weights of calves and result in reduced market weights and reduced profits.

Drought not only impacts the health of livestock, but also has negative consequences to the economic viability of the livestock industry itself. "Drought in the state of Arizona has led to many extreme economic and social pressures. Prior to the drought (year), calves and yearling cattle sales in Arizona generated over $600,000,000. It is estimated that only 1/3 or less cattle remain on the ranges post-drought. This reflects an income loss of greater than $400,000,000. Many ranchers have resorted to liquidating their herds or shipping them to a rental pasture at high costs. Loss of genetically adapted cattle / replacement herds will utilize forage resources less efficiently. Large liquidations tend to lower prices which further strains income related stresses." Personal welfare issues may arise as a result not only for the individual rancher but also for the communities that are supported by ranching operations. Communities may be impacted when consumer spending declines. "Long term impacts may include conversion of much private ranch

lands into development properties, and increased stress on already fragile environments" (Kattnig?). Additionally, periods of low prices commonly cause farmers and ranchers to have difficulty in making payments on loans, seek new loans and/or, desire a restructuring of loan conditions (Godfrey).

Eakin and Liverman found various impacts across the Southwest in response to the drought of 1995-1996. "In Texas, drought led to 30% drop in farm input sales, a drop in land prices, an increase in loan defaults, and job losses. Grain prices increase sufficiently, causing strain on ranchers supplementing feed due to poor range conditions. Cattle prices were also low due to previously high stocking rates, in response to high market prices, and recently relaxed trade of livestock with Mexico." At the same time cattle sales in Arizona increased 45% from '93-'96 due to the downsizing of operations, resulting in an overall loss of 15% of cattle operations during this time. "Small family enterprises, typically less than 50 head of cattle were hit hard, many going out of business."(Eakin and Liverman). (www.fs.fed.us/r3/prescott/orient/orient_hist.htm).

Records from the Tonto National Forest indicate that the severe drought of the 1890s caused the death of thousands of livestock animals, causing many ranches to go into bankruptcy. This was after a period of very heavy grazing conditions. Senior Forest Ranger Fred W. Croxen (1926) recalled significant stocking rates resulting in degradation to the range, which further exacerbated the impacts from drought. "Moisture did not go down to the remaining grass roots and the trails were fast becoming gullies which drained the country like a tin roof. Sheet erosion started in many places, especially on the steep slopes and the thin soil was soon washed away and only rocks were left. In response to the 2002 drought, roughly 95 percent of all cattle were removed form the Tonto National Forest. (Sprinkle *quoted from* Tronstad and Feuz 2002) After a drought many ranchers face the decision of whether or not to restock their herds at all. "The reality of the cattle industry is that it takes fewer cattle and fewer cowboys to supply the same amount of beef that it took just a few years ago. The implication is that it may not be advisable for many of the producers who have liquidated their cows to ever get back into the ranching business"(Tronstad and Feuz 2002).

Another economic impact of drought is the increased need to haul water during time of drought. "Other strategies include resting pastures, buying and storing hay, burning and feeding of emergency feed (i.e. prickly pear), and seeding abandoned fields in years of good rainfall"(Howery).

IV. MONITORING

The focus of this analysis is on forests and rangelands, comprising vegetation types organized and delineated by the Arizona NRCS Common Resource Areas described in a previous section. Regional drought monitoring needs for this task group are considered to be associated with watershed vegetation conditions, livestock forage and watershed conditions, and wildlife habitat conditions. Indicators such as total aboveground plant production, soil coverage, forage production, numbers of domestic livestock on rangeland, and wildlife numbers are all relevant to tracking impacts of drought on forest and rangelands. However, defining drought conditions on these lands and monitoring the influence of drought on watershed conditions, livestock and wildlife is problematic. Precipitation varies both spatially and temporally creating localized vegetation responses that cannot necessarily be generalized over large regions. The consequences of drought to range livestock production and wildlife populations depend upon the forage base (perennial grass, annuals, shrubs), the grazing season and the grazing management system. Additionally, droughts may reduce forage availability over the short term due primarily to limiting forage production in a given season. Forage productivity may also be reduced over a longer term if plant mortality has resulted. When this happens, watershed conditions may also suffer. Additionally, different plant communities vary in their response to seasonal moisture availability. Additionally, there is typically a lag time between the end of a drought and forage or rangeland recovery. Other influences may also drive demographic responses of wildlife species.

Specific climatic variables, especially which characterize large regional areas offer limited predictability of watershed conditions, livestock forage or wildlife habitat needs. Consequently, droughts can be expressed in different ways from a resource manager's standpoint and each scenario presents different problems with different solutions.

Drought conditions can be defined in many ways. Perhaps the simplest definition is that a drought is when you expect precipitation but don't get any. A more objective definition is when precipitation is 75% or less of the long-term average. There are several efforts to further quantify drought, i.e. the Palmer Drought Index or the U.S. Drought Monitor (http://drought.unl.edu/dm), currently used by the Forest Service. Such efforts try to use rainfall data to compare current conditions to the "average" or "normal." These indices classify general regions as to the severity of the current drought conditions. However, drought indices don't tell the whole story. How drought is defined is not necessarily relevant, and average rainfall means very little to a range manager. It is the consequences of the drought that matter and how management decisions respond to those consequences. These consequences vary depending upon a number of variables and these variables manifest differently from ranch to ranch and even pasture to pasture.

In Arizona, the various scenarios of drought influence rainfall "effectiveness" which may be more important than the total amount of precipitation. For example, did the rain come in one big storm or several small ones? How widely spaced were the storms? What was the rainfall intensity, i.e. did it produce a lot of runoff or did most of it soak in? The situation is further complicated by the fact that we get both summer and winter rain. How do we factor in dry winters vs. dry summers and/or dry summers preceded or followed by dry winters (longevity of the dry period)?

For plant species that make their primary growth in the spring, the major precipitation to consider to adjust observations to an "average year" is the fall/winter and winter/spring seasonal moisture preceding and during the growth season of interest. Consideration of extremely poor or good precipitation years prior to this period should be used to refine the estimate.

For plant species that make their primary growth in the summer, the major precipitation to consider when adjusting observations to an "average year" is the current summer and previous summer precipitation. Consideration of an extremely dry fall/winter and winter/spring period separating these two summers of precipitation may reduce or nullify the positive carry over influence of an above average previous summer precipitation to the second summer. The negative effect of a dry previous summer may be intensified, if it also was preceded by one or more summers with below average precipitation.

Additionally, drought and grazing influence different plant life forms differently. Perennial grasses, annual plants and shrubs may be more or less impacted by a particular drought cycle. Grazing influences may be more or less severe depending upon whether pastures are grazed year around or only during a particular season. A grazing system that provides periodic rest may allow for restocking sooner than one that does not.

The effects of drought may also be manifest through lack of surface water for livestock and wildlife. Some locations are dependent to some extent on springs or stock ponds to provide water for cattle. Areas where springs or ponds are the only source of water may not be useable for grazing if these sources dry up even though adequate forage may be available. During dry years or in years when light intensity rains provide for good forage growth but little or no runoff to fill stock ponds, such surface water sources may dry up (i.e. a "drought" can occur even when total rainfall is fairly normal). This lack of water forces cattle to use portions of the ranch, if any, that are watered from more dependable sources like wells and pipelines. Forcing all the cattle onto only part of the ranch may result in heavy grazing on the better-watered portion and a resulting lack of adequate forage for the entire herd.

The following table illustrates some of the potential permutations in variables that may influence management decisions during and following drought.

Table 2. Environmental and ecological variables influencing stocking decision during and after droughts.

Variable	Potential Combinations
Precipitation Pattern	Dry winter Dry summer Extended dry Wet winter Wet summer
Grazing Management	Yearlong Summer Winter Spring/Fall Rotational schedules
Forage Base (Ecological Site)	Perennial warm season grasses Perennial cool season grasses Shrubs Annuals
Restocking scenarios	Stocking rate - yearlong rest (or longer) Defer until seed set of perennial grasses Dormant season grazing only Winter use-shrubs Winter use-annuals

No particular management practice may be singled out for broad application across Arizona without due consideration given to the variable influences of climate, precipitation patterns, ecological sites and past and current management on individual allotments or even individual pastures within allotments. Because of the severity of the current drought over much of Arizona, some allotments, or certain pastures within allotments may need to be rested for entire growing seasons or longer before restocking after drought conditions. On other allotments, or pastures within allotments, some level of grazing may be acceptable on key forage species while they are dormant or after early or late growing season deferment. Range managers must consider each allotment on a case-by-case basis before deciding on the proper course of action following drought. The options available to the livestock operator to use existing or potential forage are highly dependent on how responsive the operator can be to when, where, and how many livestock graze a specific pasture.

G. Identification of Regional Drought Monitoring Needs

The sub-committee used two approaches to identify current regional drought monitoring efforts and needs. These approaches included a questionnaire to survey selected agencies, organizations and individuals, and a spatial analysis of existing data collection activities organized by NRCS Common Resource Areas.

Survey Questionnaire - Survey questionnaires were intended to help the sub-committee develop an understanding of various perspectives of how drought affects the use and management of Arizona's watersheds, rangelands, forests, wildlife and other rural issues, and develop information on the availability of drought related programs from various government agencies and other organizations. Questionnaires and complete responses can be found in Attachments II and III.

Spatial Analysis - In addition to the questionnaire, a spatial analysis approach was use to identify current drought monitoring efforts and needs, based on the availability of information from the

various climate divisions, Common Resource Areas and Game Management Units. Using GIS technology, we identified weather station locations, reservoir and stream flow monitoring, snowpack monitoring, kinds and locations of vegetation data, kinds and locations of wildlife population surveys. These were then grouped by Common Resource Area and corresponding region (See Attachment IV).

V. MITIGATION & RESPONSE

Addressing the impacts of drought can be accomplished from two approaches – modifying a practice or behavior to reduce or eliminate the impacts or reacting to drought once the impacts are being felt. Drought is a phenomenon that slowly evolves over one or more seasons and with adequate forecasting water users can prepare for drought by implementing tools to reduce their consumption or need for diminishing resources (water supplies and forage). This section will outline the various tools available to the sectors described in this chapter for reducing their vulnerability to drought (mitigation measures) and/or reacting to the impacts of drought (response).

Mitigation

Drought planning and monitoring is one way to mitigate potential drought impacts. Evolving water resource policy and management is another ongoing drought mitigation. Solutions to any drought problem should address the long-term aspect without reliance on an early end. Long-term mitigation measures should be started in the early stages of drought. Preparing for a "worst case scenario" will be useful in identifying strategies to produce long-term savings. As drought conditions worsen, pressures intensify in a variety of sectors and success is largely dependent on continuous interactions among agencies. Publicity and explanations required to motivate public drought response may appear to oppose other local and state strategies like tourism, but careful, cooperative efforts can usually overcome these problems. The following table provides recommendations for drought mitigation in Arizona to reduce the impacts of drought.

TABLE 3: Drought Mitigation Recommendations

Recommendation	LEAD/Partner Agencies	Year
Goal: Improve Water Availability Monitoring		
Secure Funding for improved monitoring of key indicators	ADWR	
Secure funding for stream gage improvements	USGS	
Augment real-time monitoring of groundwater data with additional wells statewide	ADWR	
Improve wildlife and habitat monitoring and develop an accessible and standardized database for reporting habitat conditions, populations, and human-wildlife contact incidents		
Develop an "Arizona Drought Status" strategy that communicates current drought conditions to the public and decision-makers	ADWR	On-going
Goal: Increase Public Awareness and Education		
Develop an internet site for Arizona Drought Preparedness Plan	ADWR	2004
Provide public general information on drought and wildfire issues	State Forester	On-going

Recommendation	LEAD/Partner Agencies	Year
Provide ranchers with workshops on coping with drought	NRCS/Extension	On-going
Provide public with information on wildlife issues – especially how to deal with increased interactions	AZ Game & Fish	2004 (probably already done)
Provide public with information on impacts from recreation on areas that are vulnerable to drought and how to reduce those impacts		
Prepare and update an "About Drought" informational brochure	ADWR	2004
Goal: Augment Water Supplies		
Develop program for instream flow water leasing to protect native fish and sports fisheries	AZ Game & Fish/ADWR	
Initiate partnerships with local water users and regulatory agencies to develop emergency alternative water supplies to habitat for critical species	AZ Game & Fish/ADWR	
Explore feasible water transfers	ADWR	
Goal: Facilitate watershed and local planning		
Implement Coordinated Resources Management of watersheds on public lands	NRCS	2004 – on-going
Develop risk-based vulnerability assessment for each basin /watershed	ADWR/State Lands/USFS/US BLM/NRCS	2006
Develop a water budget for each watershed/basin – integrating inflows and outflows to meet all needs including quantification of carrying capacity		
Incorporate fire management into watershed planning	State Forester	
Explore Coordinated Management of Wildlife and Livestock[33]	AZ G&F/Extension	2005
Conduct workshops on developing local or regional drought plans	ADWR	2004 – 2005
Direct state resource managers to develop drought plans for State Lands and State Parks	Governor's Office	
Goal: Reduce Water Demand / encourage conservation		
Support local development of water conservation programs	ADWR (Office of Water Conservation)	On-going
Goal: Impact Reduction		
Conduct workshops on livestock management during drought	NRCS/Extension	On-going
Address evolving water use conflicts	ADWR	On-going
Include wildlife corridors in new housing developments		
Coordinate removal of non-native vegetative species in combination with proper management and replacement of native vegetation		
Provide climate and economic forecasts of other areas in competition with local livestock operations		

[33] See Attachment V

Response

Response consists of any action taken to solve a given drought problem, from media announcements to funding or reallocation of resources. The work group has identified various response options, however, these options need to be evaluated on a case-by-case basis. No one option will work the same in all regions of the State. Factors such as intensity of drought, past mitigation actions, and economics should be considered when evaluating the appropriate option. The following table illustrates the impacts of drought and response options that could be employed to respond to those impacts.

TABLE 4: Drought Response Options

Impact		Response
Watersheds		
Ecosystem Damage	• Reduced health of vegetation • Loss of vegetation • Change in vegetative species composition • Increase of non-native vegetation • Reduced soil moisture • Reduced water quality • Increased insect infestations • Post-drought erosion due to decreased vegetative cover	• Emergency culling of livestock populations to reduce disease transmission and starvation • Emergency culling of wildlife populations to reduce disease transmission and starvation • Federal and State land management agencies impose restrictions on recreational activities • Closure of public lands to public access • Implement increasing public awareness campaign on watershed conditions • Implement emergency erosion control
Increased Wildfire Potential	• Decreased moisture in vegetation (timber) • Decreased moisture in detritus • Increased insect infestations leading to increase tree mortality	• Local communities, counties, and state and federal land management agencies impose restrictions on or cancellation of burning permits • Reduce volume of dead or dying trees due to insect damage • Increase public awareness on fire dangers
Economic	• Loss of timber production • Decreased recreational opportunities • Decreased tourism	• Media and tourism campaign on local alternatives to decrease in tourism
Impact		**Response**
Wildlife		
Animal Health	• Increased susceptibility to disease • Increased spread of diseases to other animals and humans • Reduction in reproduction • Increased animal mortality • Increased stress to endangered species • Increased predation or a reduction in available prey	• Increase public awareness on wildlife diseases and handling of impaired wildlife • Emergency culling of wildlife species • Increased predator control in critical habitat • Adjust fishing and hunting regulations and conduct public education programs to protect

		impaired fish and wildlife resources
Habitat Degradation	• Reduced availability of forage • Loss of forage • Reduction of stream flows/reservoir and lake levels • Reduction in available water supplies for drinking • Loss of aquatic habitat due to reduced flows and standing water • Reduced water quality • Disturbance to ecosystem populations and species composition • Increased human/animal interaction	• Consider careful reduction of big game and livestock populations from areas where concerns of forage resource damage arise • Supplemental feeding in critical areas • Water hauling and/or development in critical areas • Curtailment of fish stocking programs • Reclamation States Emergency Drought Relief Act of 1991
Economic	• Reduction of hunting permits • Reduction of fishing licenses • Reduction of income for private fish and wildlife-based enterprises • Reduction of recreational opportunities (birding, etc.)	• Relocate inventory of hatchery fish to alternative recreational fishing sites • Media and tourism campaign on local alternatives to decrease in hunting and fishing opportunities • Promote availability of recreational opportunities in other areas
Impact		**Response**
	Livestock	
Animal Health	• Increased susceptibility to disease • Increased spread of diseases to other animals • Reduction in reproduction • Increased animal mortality • Increased predation • Reduced weaning weights resulting in less healthy calves/lambs, etc.	• Allow for increased predator control • Emergency culling of livestock populations to reduce disease transmission and starvation • • Move livestock to areas with greater forage availability
Rangeland Availability	• Reduced health of forage • Loss of forage • Reduced availability of water supplies (stockponds, access to rivers/streams) • Increased competition with wildlife populations	• Consider careful reduction of big game and livestock populations from areas where concerns of forage resource damage arise • Implement more intensive herd management programs • Supplemental Feeding • Water Hauling • Utilize Conservation Reserve Program – Emergency Haying or Grazing • Controlled restocking rates to aid forage recovery

Economic	• Reduction in market weights of livestock • Increased supplemental feeding • Increased need for hauling water • Reduction of herd sizes or elimination of herd • Reduction of animals going to market • Reduced market prices • Increased post-drought market prices	• Assist communities and ranchers to develop supplemental natural resource employment opportunities to supplement income losses due to grazing restrictions • Emergency loans

State action may be necessary when local government capabilities cannot cope with existing or growing needs from drought impacts. Additionally, Federal programs have been developed to address drought issues. The following table illustrates the existing Federal programs and the lead Federal Agency that supports the program.

Table 5: Federal Drought-Related Programs

Program	Description	Agency
Conservation Reserve Program	During periods of severe drought, FSA may permit farmers with Conservation Reserve Program contracts to hay or graze land enrolled in CRP. Producers must have eligible CRP acreage or may lease the haying and grazing privilege on eligible CRP acreage in approved counties.	Farm Service Agency, USDA
Wetlands Reserve Program	Technical and financial assistance through the purchase of easements of cost-share agreements. Assistance in reducing flood damage, preventing soil erosion, recharging groundwater, improving water quality, and wildlife habitat improvement.	Natural Resources Conservation Service, USDA
Emergency Conservation Program	Provide financial assistance (cost-sharing) for cost of restoring farmland damaged by wind erosion, floods, hurricanes, or other natural disaster, or for emergency water conservation measures during severe droughts. Practices include providing water for livestock, restoring structures, and water conservation measures.	Farm Services Agency, USDA
Livestock Assistance Program	Provides payments to eligible producers who have suffered grazing losses due to a natural disaster.	Farm Services Agency, USDA
Livestock Compensation Program	Assistance provided to eligible owners and cash lessees for damages and losses due to drought.	Farm Services Agency, USDA
Livestock Indemnity Program	Provides partial reimbursement of livestock losses to eligible producers.	Farm Services Agency, USDA
American Indian Livestock Feed Program	Provides emergency financial feed assistance to livestock owners on tribal governed lands affected by a natural disaster.	
Environmental Quality Incentives Program	Necessary technical, educational, and financial assistance to assist owners and operators and to comply with Federal, State, and Tribal environmental laws on a voluntary basis to encourage environmental enhancements. This program is not a drought assistance program, however, practices could be used to address particular drought impacts on the land.	Natural Resources Conservation Service, USDA
Emergency Loans	Emergency loans to family farmers, ranchers, or aquaculturists for physical damage or severe production losses.	Farm Services Agency, USDA

Farm Operating Loans	Funds can be used to pay annual farm operating expenses, to purchase livestock and farm equipment, and pay costs associated with land and water development.	Farm Services Agency, USDA
Watershed Planning River Basin Surveys and Investigations	Assist Federal, State, and local agencies plan and develop coordinated water and related land resources programs. USDA cooperates in the preparation and updating of State water resources plans and other water, land, and related studies. Assistance is provided in the following areas: engineering, economics. social sciences, agronomy, range management, forestry, biology, hydrology, archaeology, landscape architecture, waste management, etc.	Natural Resources Conservation Service, USDA
National Streamgaging Program	Assistance in the form of information including monitoring of streamflow, groundwater levels, and reservoir contents. Comparison with previous droughts, drought studies, and service on drought-emergency committees. The data available from the USGS are used in responding to drought emergencies, characterizing a drought, finding alternative water supplies, and allocating water resources.	U.S. Geological Survey, USDOI
Emergency Watershed Protection Program	Technical and financial assistance to local organizations for planning and implementing watershed projects in relieving an imminent threat to life and property as a result of sudden impairment of a watershed caused by a natural occurrence including drought.	Natural Resources Conservation Service, USDA
Reclamation States Emergency Drought Relief Act of 1991	Assistance in the form of loans and grant for the purchase of water for resale or for fish and wildlife purposes; use of project facilities to store and convey water. Non-financial assistance also available to willing buyers and sellers. Programs and authorities are only applicable during times of drought.	U.S. Bureau of Reclamation, USDOI
Wildlife Habitat Incentives Program	WHIP is a voluntary program that offers private landowners cost-sharing to install practices to improve wildlife habitat. Native species and habitat will be emphasized Types of practices include: disking, prescribed burning, mowing, planting habitat, converting fescue to warm season grasses, establishing riparian buffers, creating habitat for waterfowl and installing filter strips, field borders and hedgerows.	Natural Resources Conservation Service, USDA
Economic Injury Disaster Loan	Low-interest working capital loans to small non-farm businesses and small agricultural cooperatives to help meet financial obligations arising from natural disasters. Assistance is available to small businesses dependent on agricultural production including livestock operations. Such businesses might include suppliers to farmers and ranchers, packers, shippers, food processors, and others directly dependent on trade with the agricultural enterprises.	U.S. Small Business Administration

ATTACHMENT I

ENDANGERED FISH & WILDLIFE IN ARIZONA

Common Name	Scientific Name	Location – MLRA
Kanab Ambersnail	*Oxyloma haydeni kanabensis*	
Black-footed ferret	*Mustela nigripes*	
Mexican gray wolf	*Canis lupus baileyi*	
Hualapai Mexican Vole	*Microtus mexicanus hualpaiensis*	
Lesser long-nosed bat	*Leptonycteris curasoae yerbabuenae*	
Mount Graham Red Squirrel	*Tamiasciurus hudsonicus grahamensis*	
Jaguar	*Panthera onca*	
Ocelot	*Leopardus pardalis*	
Sonoran Pronghorn	*Antilocapra americana sonoriensis*	
Masked bobwhite quail	*Colinus virginianus ridgwayi*	
Brown Pelican	*Pelecanus occidentalis californicus*	
California Condor	*Gymnogyps californianus*	
Northern aplomado falcon	*Falco femoralis septentrionalis*	
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	
Cactus Ferruginous Pygmy-owl	*Glaucidium brasilianum cactorum*	
Yuma Clapper Rail	*Rallus longirostris yumanensis*	
Bonytail Chub	*Gila elegans*	
Humpback Chub	*Gila cypha*	
Virgin River Chub	*Gila robusta semidnuda*	
Yaqui Chub	*Gila purpurea*	
Gila Trout	*Oncorhynchus gilae*	
Woundfin	*Plagopterus argentissimus*	
Colorado Pikeminnow	*Ptychocheilus lucius*	
Razorback Sucker	*Xyrauchen texanus*	
Gila Topminnow	*Poeciliopsis occidentalis*	
Desert Pupfish	*Cyprinodon macularius*	
Yaqui topminnow	*Poeciliopsis occidentalis sonoriensis*	
Sonoran Tiger Salamander	*Ambystoma tigrinum stebbinsi*	

THREATENED FISH & WILDLIFE IN ARIZONA

Common Name	Scientific Name	Location – MLRA
Beautiful Shiner	*Cyprinella formosa*	
Loach Minnow	*Rhinichthys cobitis*	
Spikedace	*Meda fulgida*	
Little Colorado Spinedace	*Lepidomeda vittata*	
Apache Trout	*Oncorhynchus apache*	
Yaqui Catfish	*Ictalurus pricei*	
Sonora Chub	*Gila ditaenia*	
Desert Tortoise	*Gopherus agassizii*	
New Mexico ridgenose rattlesnake	*Crotalus willardi obscurus*	
Chiricahua leopard frog	*Rana chiricahuensis*	
Bald Eagle	*Haliaeetus leucocephalus*	
Mexican spotted Owl	*Strix occidentalis lucida*	

ENDANGERED PLANTS IN ARIZONA

Common Name	Scientific Name	Location – MLRA
Nichol's Turk's head cactus	*Echinocactus horizonthalonius* var. *nicholii*	
Arizona hedgehog cactus	*Echinocereus triglochidiatus* var. *arizonicus*	
Huachuca water-umbel	*Lilaeopsis schaffneriana* ssp. *Recurva*	
Brady pincushion cactus	*Pediocactus bradyi*	
Peebles Navajo cactus	*Pediocactus peeblesianus* var. *peeblesianus*	
Arizona cliffrose	*Purshia subintegra*	
Arizona agave	*Agave arizonica*	
Kearney's blue-star	*Amsonia kearneyana*	
Sentry milk-vetch	*Astragalus cremnophylax* var. *cremnophylax*	
Holmgren (Paradox) milk vetch	*Astragalus holmgreniorum*	
Canelo Hills ladies'-tresses	*Spiranthes delitescens*	

THREATENED PLANTS IN ARIZONA

Common Name	Scientific Name	Location – MLRA
Welsh's milkweed	*Asclepias welshii*	
Silver pincushion cactus	*Pediocactus silveri*	
San Francisco Peaks groundsel	*Senecio franciscanus*	
Navajo sedge	*Carex specuicola*	
Cochise pincushion cactus	*Coryphantha (Escobaria) robbinsorum*	
Jones cycladenia	*Cycladenia humilis* var. *jonesii*	
Zuni (rhizome) fleabane	*Erigeron rhizomatus*	

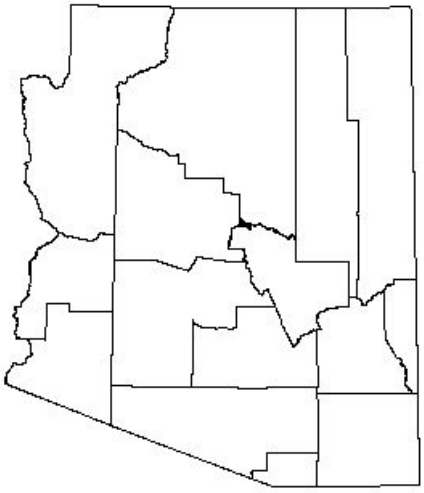
ATTACHMENT II - SURVEY

Governor's Drought Task Force - Arizona

Environmental Health, Watershed Management, Livestock and Wildlife Workgroup

Your Agency or Organization is being asked to provide the following information to help develop a statewide, comprehensive monitoring and assessment program and identify response options that can be used to mitigate the impacts of drought on wildlife, livestock, and ecosystems in the State of Arizona.

Agency Contact, Title	
Agency Name	
Address	
City, State Zip	
Phone Number	
Email Address	



If your responses to this questionnaire are for a specific area of the State, please indicate on the map the approximate location your answers apply to.

1. Identify your agency's primary interest or involvement in the use and management of Arizona's watersheds, rangelands, forests, and wildlife?

	Federal land		Watershed management
	State land		Forest management
	Tribal land		Range management
	Private land		Wildlife Management
	Upland Wildlife		Water supply
	Aquatic Wildlife		Water quality
	Livestock Grazing		Recreation
	Hunting/Guiding		Wildfire

List Others

2. Does your Agency have or use an official definition of drought? YES_____ NO_____
If you answered YES, please provide your definition:

3. What primary indicators does your agency use to determine whether these lands are experiencing drought conditions?

	Precipitation		Plant production
	Snowpack		Plant cover
	Lake/reservoir levels		Plant mortality
	Stockpond water		Forage quality
	Water table depth		Livestock numbers
	Stream flow		Wildlife numbers
	Soil moisture		Animal health - Wildlife
	Water quality		Animal health - Livestock
	Burned acres		Animal mortality - Wildlife
	US Drought Monitor		Animal mortality - Livestock
	Spring Flow		Economic
	Palmer Drought Severity Index		

List Others

4. Based on information collected by your Agency, what are reasonable ranges for mild, moderate, and severe drought?

Indicator	Mild	Moderate	Severe
Precipitation (% of average)			
Stream flow (% of average)			
Lake/reservoir levels (% of storage capacity)			
Stock pond water (% of available)			
Snowpack (% of average)			
Soil moisture (% of average)			
Plant production (% of average)			
Plant cover (% of average)			
Plant mortality (%)			
Livestock numbers (% of average)			
Wildlife numbers (% of average)			
Animal mortality (%)			
Others indicators			

5. Identify data from your agency that would be useful for monitoring drought in Arizona?

Frequency – How often data is collected (i.e. daily, monthly, yearly etc)
Distribution – Where is data collected (i.e., statewide, counties, watersheds,)

Data Type	Brief Description	Frequency	Distribution	Web Address or Contact

6. Identify assistance or programs that your Agency administers to help mitigate the impacts of drought, or provide direct assistance during drought that should be included in the Arizona Drought Plan.

Program Name	Brief Description	Web Address or Contact

7. What kind of land or water management changes do you think could be implemented in response to drought conditions or to mitigate the impacts of drought?

8. Other Suggestions or Comments

ATTACHMENT III
Summary - Survey Response

(still need to put this into Table format – have not received anything from Derek yet)

Survey audiences were organized into statewide and regional categories. Statewide survey recipients included… Responders included Don Metz- Assistant Field Supervisor, US Fish and Wildlife Service (USFWS), John W. Hunt- Assoc. Director of Animal Services, Arizona Dept. of Agriculture (ADA), Linda Taunt- WQD HSAS, Arizona Dept. of Environmental Quality (ADEQ), Jeff Stuck- Safe Water Drinking Program, Arizona Dept. of Environmental Quality, Richard Rico - Arizona Game and Fish Department, and Ron Lee- Arizona Commission of Indian Affairs (ACIA).

Responses to each question are summarized below.

1. Federal land (USFWS, ADA, ADEQ), tribal land (ACIA, ADA), private land (USDA, ADEQ), upland wildlife (USFWS), aquatic wildlife (USFWS, ADEQ), livestock (USFWS, ADA, ADEQ), hunting (USFWS), watershed management (USFWS, ADEQ), forest management (USFWS, ADEQ), range management (USFWS, ADA, ADEQ), wildlife management (USFWS, ADEQ), water supply (ADA, USFWS), water quality (USFWS, ADA, ADEQ), recreation (USFWS, ADEQ), and wildfire (USFWS, ADEQ) were indicated as interests and concerns across the state.
2. No agency indicated an official definition of drought.
3. Arizona Department of Agriculture (ADA) uses livestock health and the US Drought Monitor as indicators to determine the status of drought conditions. Other agency's indicators include precipitation (ACIA, ADEQ), snowpack (ACIA, ADEQ), lake/reservoir levels (ACIA, ADEQ), water table depth (ACIA, ADEQ), streamflow depth (ADEQ), water quality (ADEQ), spring flow (ADEQ), word of mouth (ACIA), and notification from water suppliers (ADEQ).
4. No agencies responded with ranges for mild, moderate, and severe droughts for any indicator.
5. ADEQ identified several types of data which may be useful for monitoring drought. Drinking water quality is monitored on varying frequencies throughout the state and over 90 contaminants are monitored. Water quality for surface water, groundwater, and lakes and reservoirs are also monitored. This is done on a quarterly basis and rotated through watersheds (Contact is Wayne Hood). Macrovertabrates are also monitored. Algae and insects are monitored each spring throughout the state (Contact is Patti Spindler)
6. ACIA identified an outreach program to tribal communities which can help mitigate impacts associated with drought. For more information contact: debra.krol@indianaffairs.state.az.us.
   ADEQ has two assistance and training programs to help mitigate for drought impacts. These two are the Drinking Water Tech. Asst. and DW Training, which assist with information related to curtailment decisions and deal with training on water conservation and efficiency practices, respectively.
7. ACIA indicated statewide water restrictions, which regulate usage by punishing those who break the rules, and more public education on water shortage versus water usage could help mitigate impacts of drought. ADEQ cited integrated knowledge of drinking water system capacities and of those with water deficits in drought to facilitate use during drought situations.
8. No agencies responded with further suggestions or comments.

Regional categories included the Northwest, comprised of Common Resource Areas primarily associated with MLRA 30, the Southwest, comprised of Common Resource Areas primarily associated with MLRA 40, the Northeast, comprised of Common Resource Areas primarily associated with MLRA 35, the Southeast, comprised of Common Resource Areas primarily associated with MLRA 38, 40, and 41, and the Central region comprised of Common Resource Areas primarily associated with MLRA 38, 39, and 40.

Responders from the Northwest were John Earle- Refuge Operations Specialist, Havasu National Wildlife Refuge, and USDA-NRCS.

Responses to each question are summarized below.

1. Primary concerns indicated were federal lands (HNWR), upland wildlife (HNWR), aquatic wildlife (HNWR), hunting/guiding (HNWR), watershed management (HNWR), forest management (HNWR), wildlife management (HNWR), water supply (HNWR), and quality (HNWR), recreation (HNWR), and wildfire (HNWR).
2. No agency indicated an official definition of drought.
3. Primary indicators used included precipitation (HNWR), lake/reservoir levels (HNWR), water table depth (HNWR), stream flow (HNWR), and wildlife numbers (HNWR).
4. No agency responded.
5. HNRW has a remote automated weather station *(RAWS)*, which is collected hourly throughout the refuge. This is used to help prevent fires in critical times due to weather. Contact is: www.dri.edu/index.html. HNRW also records evapo-transpiration at three study sites on the refuge. Evapo-transpiration is recorded every 20 minutes. Unfortunately, in 2005 the number of sites will fall from three to only one. Contact is Craig Westenburg: cwesten@usgs.gov
6. No agency responded.
7. No agency responded.
8. No agency responded.

Southwest responders were Ken Edwards- Refuge Manager, Imperial National Wildlife Refuge, Refuge Manager, Kofa National Wildlife Refuge, and Tom Alexander- Refuge Manager, Cibola National Wildlife Refuge.

Responses to each question are summarized below.

1. Responders indicated federal land (INWR, KNWR, CNWR), upland wildlife (INWR, KNWR), aquatic wildlife (INWR), hunting/guiding (INWR, KNWR), watershed management (INWR, CNWR), forest management (INWR), wildlife management (INWR, KNWR, CNWR), water supply (CNRW), recreation (INWR, KNWR, CNWR), and wildfire (INWR, CNWR) as primary interests
2. No agency indicated an official definition of drought.
3. Responders use precipitation (INWR, KNWR), soil moisture (CNWR), burned acres (CNWR), plant production (KNWR, CNWR) and mortality (KNWR), forage quality (KNWR), wildlife numbers (INWR, KNWR, CNWR)), wildlife mortality (CNWR, KNWR), wildlife health (INWR, KNWR, CNWR) and forest health (KNWR) as primary indicators of drought conditions
4. The Kofa NWR indicated ranges of mild, moderate, and severe drought conditions for precipitation and wildlife numbers. The ranges for precipitation are 60%, 40%, and 20%, respectively. Ranges for wildlife numbers are 90%, 75%, and 50%, respectively.
5. The Kofa NWR indicated precipitation data from the refuge would be useful in monitoring drought. 8 rain gauges are located throughout the refuge and collected in varying frequency.
6. Kofa NWR hauls water to critical areas for wildlife in order to help mitigate the impacts of drought. The program name is Wildlife Waters.
7. Land or water management changes in response to drought conditions are limited on the Kofa NWR, because 80% of the refuge is designated wilderness. Therefore, caution must be used in he relief of impacts.
8. No comments.

Northeast responders were Dan Bloedel- District Conservationist, USDA-NRCS.

Responses to each question are summarized below.

1. Primary concerns indicated were tribal lands, upland wildlife, livestock grazing, watershed and range management, wildlife management, water supply and quality, as well as recreation.
2. No agency indicated an official definition of drought.
3. Primary indicators used by NRCS include precipitation, snowpack, plant production, plant cover, and also economic indicators.
4. Based on the information collected by NRCS, the reasonable ranges for mild, moderate, and severe drought are 70%, 60%, and 50% of averages, respectively. These ranges were given for all Indicators listed.
5. Plant production is collected twice per year and collected per district. An assessment of range plant growth and production may be useful in drought monitoring.
6. The Emergency Watershed Protection Program is administered through the agency and should be included in the state drought plan. Contact is dbloedel@ag.usda.gov
7. Standard conservation practices (wise use of plants, soil and water, no overgrazing, etc..) and careful irrigation practices may help mitigate drought impacts.
8. Additionally, the Navajo Nation Department of Water Resources should be contacted for more information.

Southeast responders were Walter Meyer- Winkelman NRCD.

Responses to each question are summarized below.

1. Areas of interest or involvement include federal, state, private, and tribal lands, upland wildlife, livestock grazing, hunting/guiding, watershed, forest, and range management, recreation, and wildfire.
2. Responder indicated that if there was an official definition of drought they were not aware.
3. Primary indicators used to determine drought conditions include precipitation, lake/reservoir levels, stockpond water, water table depth, soil moisture, burned acres, plant production, mortality, and cover, forage quality, livestock numbers, livestock health, and livestock mortality.
4. Reasonable ranges, in percentage, were indicated for precipitation (mild = 50% and severe = 40%), stock pond water (severe = empty), plant production (severe = 10%), and livestock numbers (severe = 20%).
5. No data is collected, but NRCS would data needed for district.
6. No programs were indicated to assist with or mitigate for drought conditions.
7. No comments.
8. No comments.

Central Region responders were Charlie Ester- Manager, Water Resource Operations, SRP, Kent Ellett- Apache-Sitgreaves National Forest, Mitchel White- Forest Rangeland Ecologist, Apache-Sitgreaves National Forest, Jim Probst- Forest Hydrologist, Apache-Sitgreaves National Forest, Grant Loomis- Forest Hydrologist, Tonto National Forest, and Chic Spann- Regional Hydrologist, Forest Service Southwest Region.

Responses to each question are summarized below.

1. Federal land (ASNF, TNF), private land (ASNF), upland and aquatic wildlife (ASNF), livestock (ASNF), hunting (ASNF), watershed (ASNF, TNF, SRP) and forest management (ASNF, TNF, SRP), range (ASNF, TNF) and wildlife management (ASNF, TNF), water supply (ASNF, TNF, SRP) and quality (ASNF, TNF, SRP), recreation (ASNF, TNF), and wildfire (ASNF, TNF, SRP) were indicated as interests for the region.
2. ASFS indicated their drought policy, including the definition of drought, is in draft form (SPI index is used in evaluating conditions). The defined level is an SPI of -1 or below for

the preceding 8-12 month period and for a length of time to include a winter and summer precipitation period.
SRP defines drought, meteorologically speaking, as two or more years below normal precipitation. This, they say, may and probably will not result in a hydrologic drought or water supply drought for SRP shareholders, but the caution flag is certainly raised.
TNFS defined drought as occurring when the SPI drops below -.7. This may be revised to -.75 or even -1 to be consistent with the Western Regional Climate Center's definition of moderately-dry conditions.

3. Primary indicators used include precipitation (ASNF, SRP, TNF), snowpack (ASNF, SRP), lake/reservoir levels (ASNF, SRP), stockpond water (ASNF, TNF), stream flow (ASNF, SRP), soil moisture (ASNF), US drought monitor (ASNF, SRP, TNF), spring flow (SRP, ASNF), and the Palmer Drought Severity Index (ASNF, SRP). plant production (ASNF, TNF), plant cover (ASNF), plant mortality (ASNF, TNF), forage quality (ASNF), and livestock numbers (TNF).
   TNF and ASNF also listed the SPI, stating "when the SPI drops below -.7 a Forest Drought Team is assembled to assess site specific conditions on the ground. In addition to the SPI, the team considers such factors as: local precipitation data, current range conditions, current stocking levels, available water, and management intentions of the grazing permittees" SPI is used as a trigger to initiate field investigations, not as an absolute.
4. Based on information collected by SRP, ranges for precipitation, stream flow, lake/reservoir levels, and snowpack are listed below (percentage of normal) based on mild, moderate, and severe drought. Precipitation ranges are >75%, 51-74%, and <50%, respectively. Stream flow ranges are >67%, 66-34%, and <33%, respectively. Lake/reservoir level ranges are >80%, 50%, and <25%, respectively. Snowpack ranges are >70%, 26-69%, and <25%, respectively.
   TNF cited criteria published by Western Regional Climate Center for SPI. Mild, moderate, and severe were given as -.75 to -1.24, -1.25 to -1.99, and <-2.0, respectively.
5. ASNF indicated precipitation as data that would be useful for monitoring drought. They currently have rain gauges across the district and hope to have 10 additional rain gauges out soon. The gauges are checked monthly.
   Other data from ASNF includes plant health/vigor, perennial plant cover in relation to potential, forage utilization levels, range/ecological condition, forage production, soil moisture, effective precipitation, and water availability. Contact for this info is Mitchel White: mwhite04@fs.fed.us
   SRP indicated that precipitation, streamflow, and reservoir storage data would be useful for monitoring drought. This data is kept for the Salt River and Verde River systems. Precipitation and reservoir storage is collected daily, while streamflow is collected hourly. Precipitation and streamflow is collected through various gauges throughout the watershed and reservoir storage is collected for all lakes on the Verde and Salt River systems.
   TNF indicated plant production and vigor data are collected and used when deciding to restock allotments following a drought. Contact is Buck McKinney: brmckinney@fs.fed.us
6. TNF utilizes conservative stocking rates and manages on a site by site basis in order to help mitigate or lessen the impacts of drought.
7. SRP indicated that forest health restoration would help mitigate the impacts of drought and help return to a more natural water cycle, reduce fire hazards, lessen forest diseases, and bark beetle attacks. Also, conservation efforts may help reduce demand during droughts. Reasonable growth management, which takes into account water supply availability, will also help to mitigate these impacts.
8. Additionally, the USFS provided a copy of Apache-Sitgreaves National Forests Drought Management Guidelines.

ATTACHMENT IV
MONITORING LOCATIONS

INVENTORY OF MONITORING LOCATIONS FOR EACH RESOURCE AREA

MLRA	SNOTEL Sites	Snow Course Sites	Precipitation Sites	Recorder Index Wells	Transducer Index Wells	Index Wells	Stream Gages
30-1	0	0	2	0	0	5	1
30-2	0	0	1	3	1	17	1
30-3	0	0	0	0	0	0	0
31-1	0	0	0	0	0	0	0
31-2	0	0	0	0	0	3	1
31-3	0	0	0	0	0	1	0
35-1	0	0	4	0	19	72	3
35-2	0	0	8	0	0	15	13
35-3	0	0	0	0	0	1	2
35-4	0	0	0	0	0	0	0
35-5	0	0	1	0	0	0	5
35-6	0	0	0	0	0	0	0
35-7	0	0	1	0	0	9	1
35-8	0	7	0	0	0	0	0
35-9	0	0	0	0	0	0	0
38-1	0	0	10	1	2	72	20
38-2	1	0	5	0	1	22	7
38-3	0	0	0	0	0	0	1
39-1	14	18	9	1	9	103	3
40-1	0	0	3	1	0	39	8
40-2	0	0	3	8	1	202	7
40-3	0	0	5	5	0	177	6
41-1	0	0	6	0	0	18	5
41-2	0	0	3	2	1	38	5
41-3	0	0	6	3	4	45	9
CC&N	0	0	10	4	2	115	1

ATTACHMENT V
Example of Proposal
for
Integrated Wildlife/Livestock Planning

Ranching for Wildlife, A Proposal for Arizona

Prepared By: Manuel Nikel-Zueger
For Benny Aja and Chuck Lange

Overview

In Arizona, the quantity and quality of wildlife is not optimal. This is the result of many contributing factors, not the least of which is the imbalanced relationship between the rights of private landowners and wildlife, which is managed by the State Game and Fish Department.
Many landowners, hunters, outfitters, and guides believe that a "Ranching for Wildlife" program similar to those that exist in other western states[34] is a fundamental step towards creating healthier wildlife with better habitat while fully acknowledging and respecting the property rights of private landowners.

Description of the Problem

Landowners, principally ranchers and other agriculturalists, whose livelihoods rely upon the careful management of natural resources, are encumbered in many places by elk, deer (couse deer and mule deer), antelope, and/or javelina. For example, an elk consumes a substantial amount of forage, perhaps seventy-five percent the forage a cow consumes. Deer and antelope consume less, but deer, antelope, and elk all eat the same vegetation that cows eat. Therefore each additional big game animal on a ranch reduces (to a varying extent) the number of cattle that can be run on a ranch. In Arizona, this problem has grown considerably because elk populations have grown substantially in the past two decades. Not only have numbers grown, but elk have expanded into more territory.

Consumption of forage is not the only cost wildlife imposes on private property owners. Elk are the most destructive. They often tear down fences, though deer can also, while antelope either go under fences or between the wires. Downed fences have to be repaired, which incurs material and labor costs, and time is spent finding and returning cattle.

Elk and other wildlife also rely on the improvements that ranchers and other landowners provide for their operations, such as wells and extensive pipeline systems, dirt tanks (which capture run-off rain water), salt, and protein supplements. Wildlife also benefit from the restricted access hunters have on private land, which can encourage the residence of wildlife.
Landowners want to control the access hunters have on their land in order to ensure that the land is respected. Landowners attempt to minimize unnecessary roads, trash, and even the occasional dead cow or calf killing. In addition, landowners are legitimately concerned

[34] California, Colorado, New Mexico, and Utah are examples of the larger programs. For a description of these and other Ranching for Wildlife programs, see: Donald R. Leal and J. Bishop Grewell. "Hunting for Habitat: A Practical Guide to State—Landowner Partnerships." Bozeman: Political Economy Research Center. 1999

about preventing any easements by prescription, which limit the landowner's property rights and ability to be a steward of the land. Stricter access controls on private lands are largely the result of increased human populations in the state, and increased hunting pressure, both of which have increased trespassing.

Unfortunately, the cost that wildlife, especially big game wildlife, imposes on landowners does not create incentives for progressive steps to manage for wildlife, despite the fact that landowners enjoy wildlife. This is because private landowners have little recourse to the benefits that wildlife could otherwise provide. The benefits of seeing big game wildlife or charging access fees is too small relative to the costs wildlife impose. In fact, Arizona is the only western state is here landowners do not receive any form of compensation for damages caused by wildlife.

Making matters worse is that the quality of management provided by the State's Game and Fish Department is less than satisfying. This view is not only held by private landowners but also by many hunters. Landowners complain about working with Game and Fish, noting generally that most efforts are a waste of time. Many landowners are wary about dealing with the agency because most grants for habitat improvements or other infrastructure improvements that would benefit wildlife are contingent on Game and Fish obtaining public access. With respect to big game hunters, they are given only a short time frame during which they can hunt. Short seasons also mean that hunter are out at the same time, and if they have done their scouting, hunter densities in an area can be high, leading to less enjoyable and less successful hunting experiences. High densities of hunters can also lead to a greater negative impact on the natural resources. In all, management of our wildlife and natural resources, as well as hunting experiences, can be improved.

Some argue that private landowners exercise their private property rights by restricting access while offering hunters either access for a fee and/or guided hunts for a fee. While private property owners certainly can (and some do) receive revenues from such measures, landowners are merely trying to capitalize on their resources in order to stay in business. That landowners are due compensation for damages caused by wildlife is an issue distinct from a landowner's right to charge access fees on or through private lands. Revenues from access or guided hunt fees never outweigh the costs of damages.

At the heart of this issue is the question of the bundle of rights that belong to private property with respect to wildlife. Do landowners have any right to compensation for the losses they incur as a result of damage done and forage consumed, by wildlife, principally big game such as elk, deer, antelope and javelina? The State of Arizona receives all revenues from hunting whereas private landowners go empty-handed while paying many of the costs of providing for wildlife by way of land, forage, water, roads, and other infrastructure. Private Landowners should share in the revenues. Understanding that incentives matter, if private property owners were to have a stake in the hunting industry, they would certainly manage their ranches for both cattle and wildlife.

Ranching for Wildlife: The Idea

A certain number of hunting tags for all big game species that are found on a ranch are given to the ranch (landowner) at the price for which the hunter would purchase them from the state if he had drawn a tag. These tags are completely transferable and saleable. This is a form of compensation to the landowner, which gives him a definitive stake in managing the ranch in a way that incorporates wildlife as an essential part of the mix. A Ranching for Wildlife program in Arizona most be an explicit recognition of the right a landowner has to compensation for damages, especially since there is no such recognition in Arizona.
In order to make this program acceptable to the public and to the State Tame and Fish Department, the landowner must participate in a "Wildlife Management Plan" that is specific to the ranch. Annual review by a board comprised of the landowner, a representative from the Game and Fish and an independent third party (perhaps by a qualified professional from the University of Arizona Extension Service) will review progress towards the implementation of the management plan and its effectiveness. In addition, a proportion of the tags allocated to the landowner will be allotted as a public access tag on the ranch.

The Pilot Program

Before a wide-scale program is implemented, a pilot program should be adopted in order for the State to familiarize itself with the program and to identify ways in which the program can be improved. A pilot program would comprise several ranches which are identified as prime candidates with respect to certain criteria such as ranch size and wildlife (big game) populations. The duration of the pilot program is negotiable but a three-year trial would allow sufficient time to judge the effectiveness of implementing the program, as well as observing initial results. With this approach, changes could be considered and attempted, perhaps even by adding one or two additional ranches to the program. The pilot program could also be extended an additional year or two if it is believed that more time is needed to make the process more effective. The pilot program would not exceed five years before the policies and procedures become final,

Preliminary Policies and Procedures

- A landowner must have at least 2,000 acres of private land in order to participate.

- Landowners that border one another, none of which own 2,000 acres, can submit an application (if their combined private lands are at least 2,000 acres) that their lands be managed together in one management plan.

- A task force comprised of two Game and Fish Department personnel, two eligible landowners or their representatives, and two University of Arizona Extension Service personnel will draw up and agree on norms, by majority vote, for the application procedure and the method of scientific estimation of big game wildlife populations.

- Each aspiring participant must file an application with the State Game and Fish

Department that includes legal description of all participating lands and adequate maps that indicate the topography and the borders of the participating lands.

- The application must include scientific estimates of all big game wildlife that resides on the applicant's lands. The method of estimation approved by the task force must be used by all participants in the program.

- Upon approval of the application, a wildlife management plan that specifies the landowner's short term and long-term objectives and the actions that will be taken to achieve those objectives must be submitted.

- State and federal lands to which a landowner has a lease can be included in the landowner's "Wildlife Management Plan". (Those lands, however, cannot be counted towards the 2,000 acres of private land required for participation.)

- Management of state and federal lands in the Ranching for Wildlife program does not in any way prevent the public from accessing those lands to which they have legal access.

- Upon approval of the wildlife management plan, the applicant will receive a license for the area described in the management plan.

- Licenses are valid for five years. Landowners participating in the pilot program will be licensed throughout the term of the pilot program. As the maximum possible length of the pilot program is five years, all pilot program participants must reapply at the conclusion of the pilot program.

- The number of transferable tags allocated to a landowner for each big game species (elk, deer, antelope, and javelina) will be calculated with respect to the number of acres of private property and the number of animals that use the private lands. Specific means of calculating tag numbers will be negotiated by the task force and will be subject to alteration during the pilot program. Because of the nature of transferable wildlife tags and each management plan, all participating landowners will have ranch specific harvests. In other words, there should be some measure of flexibility for setting tag numbers, given varying management objectives.

- Licensed landowners will have a one hundred day season window for all hunts on their private lands and the lands they lease. Flexible season dates allow landowners the necessary time to harvest a specific amount of animals while ensuring high quality hunts and decreased hunting pressure.

- The landowner will allocate one in ten of his or her transferable wildlife tags per specie for a public access lottery. (For example, if a particular landowner is only allocated five tags a year, in this case, the ranch specific public access tag would be granted every second year.) Ranch specific public access tags, like any other

tag from a landowner are usable only on the landowner's lands, subject to the norms delineated in the management plan.

- The Arizona State Game and Fish Department will be responsible for a lottery sale of ranch specific public access tags for each landowner. The monies collected from the lottery are payable to the landowner, with the exception of the Arizona State Game and Fish Department's administrative costs.

- When a hunter draws a ranch specific public access tag from the lottery, that hunter must wait three years before purchasing another ticket for the same management area.

- Only Arizona residents may participate in drawing ranch specific public access tags. The price per ticket will be $20 and the maximum number of tickets that can be bought per person is 5. Tags that are not won are not transferable.

- A hunter that has purchased a transferable tag or won a ranch specific public access tag can hunt with rifles, bows, and muzzleloaders at any time during a landowner's approved season dates.

- Participating landowners will undergo a performance review annually by a review Board, which is comprised of one Game and Fish Department personnel, the landowner or his or her representative e and one University of Arizona Extension Service personnel. Landowners whose management plans include state and/or federal lands will invite one official from the respective departments to participate in the review.

- Landowners are solely responsible for the implementation of the objectives enumerated in their specific management plans.

- Failure to comply with the stated objectives in their management plans may result in the loss of the landowner's transferable wildlife tags.

- The final decision to terminate any landowner's wildlife management plan will not be given to the review board. The review board may formally declare that a landowner's plan is subject to termination, at which time a larger board will make a final decision. This larger board will comprise of participating landowners, two AG&F personnel, two State Land Department personnel, and two UA Extension Service personnel. Decisions are reached by simple majority.

- A landowner may terminate his or her participation in the Ranching for Wildlife program with written notification to the Arizona State Game and Fish Department and the return of his or her license. Transferable tags still held by the landowner must be returned.

ATTACHMENT VI

Impacts of drought on Arizona's wildlife and in increasing urban human-wildlife conflicts

The confounded influence of ecology, animal behavior, and human societal values

Impacts of drought on Arizona's wildlife and in increasing urban human-wildlife conflicts

The confounded influence of ecology, animal behavior, and human societal values

Presented to the Arizona Governor's Drought Task Force by
Climate Assessment for the Southwest (CLIMAS)
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Executive Summary

A comprehensive look at drought impacts on wildlife, particularly wildlife involved in urban conflicts with people, is important because:

- Drought is a normal part of Arizona's climate, and thus will continue to present challenges to wildlife, people, managers, and governments
- Understanding how animals respond to drought may allow for more proactive planning and public education programs, and fewer conflicts between humans and wildlife
- Many factors combine to put stress—used hereafter to refer to physiological changes in an animal, such as weight loss and reduced reproductive ability—on wildlife populations: urban development, habitat degradation, water table reduction, riparian area loss, and the duration and timing of severe drought conditions among them
- Thus far, very few studies have attempted to separate these and their impacts on wildlife from one another
- Wildlife and humans have an increasing potential for contact because urban areas in Arizona are growing at an unprecedented rate, and requiring more land and water resources
- Normal wildlife adaptations to drought, such as a change in diet or migration, may not be possible with grazing competition from cattle and human infrastructure development, respectively
- Ongoing drought has exceeded the adaptive capabilities of some species, causing what many people see as "abnormal" contacts between humans and wildlife in urban areas
- Due to recent conflicts between humans and bears, mountain lions, and bobcats in just the Tucson, AZ area, there is increased media attention and public demand for non-lethal solutions to "problem wildlife"

Data , information, and statistical results were obtained using the following methods:

- Personal contacts with wildlife managers, attendance at wildlife conferences
- Newspaper and other media report analysis
- Statistical analysis of urban wildlife/human conflict reports from 1993 to 2002

CLIMAS reviews of available wildlife data show general impacts of drought on wildlife:

Direct:

- Reduced food, surface water, and vegetative cover
- Decreased reproductive success and survivorship
- Increased competition between livestock and wild animals for grazing

Indirect:

- Alteration of habitat, forage, and prey populations due to drought-related fires

Urban development introduces further pressures on wildlife populations:

Direct:

- Increased urbanization/suburbanization expands into formerly-rural or wild areas, leading to contacts between people and animals that use the habitat
- Decreased total habitat limits access to food, water, and habitat resources
- Isolation among metapopulations of species, such as the Sonoran Pronghorn, which over time may further reduce reproductive success and normal migration

Indirect:

- Reduced water tables cannot support native vegetation, which reduces riparian area trees and vegetation

- Reduced/eliminated surface water flows limit usable habitat; 90% of pre-settlement riparian areas in the Southwest have disappeared in the past century
- Wildlife inability to migrate seasonally or move away from dry, less productive habitat due to human construction of cities, roads, etc.

Humans exacerbate already existing pressures on wildlife during drought, and also introduce a constant impact through water draw from aquifers and surface water supplies.

- In years when precipitation is merely at or below average levels, biologists, climatologists, and the public may have to consider ecosystems to subsist in a permanent "human-induced drought," since human water draw results in less-than-average amounts of water available to an ecosystem even when precipitation levels are average
- While above-average precipitation might relieve the effects of a human induced drought, the continued water demand from water systems in a state of climatological drought seems to be enough to overwhelm adaptive capabilities of many plant and wildlife species

While many species have adapted behaviorally or genetically to an arid climate, drought has varying impacts and requires special adaptations:

- Behavioral adaptations include timing activity to cooler times of day, or shifting grazing, hunting, or foraging activities to riparian or vegetated areas
- Genetic adaptations include special capabilities to survive without drinking for long periods of time; for example, Kangaroo rats can concentrate their urine to reduce water loss, and burros can use moisture stored in body tissue, losing massive amounts of weight to survive short dry spells
- Carnivores (mountain lions, coyotes) normally do not need to drink water, since they obtain moisture from prey; in drought, prey is scarce and water requirements increase, so these animals become dependent on surface water supplies
- Ungulates (pronghorn, mule deer) can obtain most required moisture from forage, but depend on surface water during lactation and breeding; during drought they need sufficient surface water to digest desiccated forage
- Aquatic animals are entirely dependent on surface water, and are impacted severely before other species
- Urban wildlife may react more to precipitation than to drought; skunk, coyote/fox, amphibian/lizard, and overall mammal conflicts in Tucson over the past 10 years decreased during cool and warm seasons with higher precipitation levels

Important mitigation measures already in progress include:

- **Wildlife waters**, holding tanks constructed and sometimes filled by AGFD throughout known animal ranges, and distributed through less densely populated ranges to distribute grazing stress during drought. These tanks allow ungulates and other animals to digest dry forage in habitats that otherwise could not support them, researchers posit, during drought (Burch and Grossi 1997). They are especially crucial for endangered species such as Sonoran Pronghorn, since the Arizona population has been cut off from its historical water sources.
- **Forage enhancement programs**, which offer managers an additional tool, along with water tanks in the wilderness, to help endangered populations such as the Sonoran Pronghorn grow.

Drought and wildlife, recommendations and actions

- Develop a comprehensive "Drought response plan for wildlife," similar to the plan developed by the Utah Division of Wildlife Resources, to include impacts and mitigation for game, endangered, urban, and as many other species as possible
- Begin, or improve, in some cases, regular monitoring of species populations, ranges, and movement patterns to determine baseline ecological health; currently the range of "normal" behavior and movement for many species remains unknown and unstudied
- Record all urban wildlife complaints in a standardized database that the Game and Fish Department, Fish and Wildlife Service, National Park Service, Forest Service, BLM, and other agencies directly involved in the human/wildland interface could use
- Enhance public education programs to emphasize proactive, rather than reactive, measures to reducing human/wildlife conflicts in urban areas; these include the following points:
  - Guidelines on daily living: no feeding of wildlife, keep pets indoors, plant native vegetation, etc.
  - Suggested behavior in the case of an aggressive animal encounter
  - Strategies for maintaining educational/aesthetic contacts (e.g. wildlife viewing while hiking, bird watching in the backyard) without encouraging conflicts
- Include wildlife corridors in new developments, and reduce attractants and water use by restricting non-native vegetation, fountains and pools, and wildlife-feeding
- Recognize that humans and animals inevitably share limited habitat and resources, and while *contacts* will continue, people can act to reduce potential *conflicts*

In the future, increased understanding of the relation of drought to conflicts between humans and wildlife may be treated as not only a possibility but also as a *necessity*. Arizona will continue to experience drought and urbanization, and we can only benefit from preparing new ways to address ongoing conflicts in an educated and humane manner.

"We forget that the water cycle and the life cycle are one."

—*Jacques Cousteau*

Introduction

Arizona entered a multi-year drought in the late 1990s, and in 2002 suffered a record year of minimal precipitation. Urban areas felt one impact of drought through an influx of wildlife species in yards, gardens, and parks. Phoenix residents recalled the dozens of black bears (*Ursus americanus*) that had roamed downtown in 2000, and local newspapers carried headlines such as, "Drought-stricken animals prowling urban landscape." Conversation at the post office included worries about the "twenty pets [that had] been taken by coyotes" in some Phoenix neighborhoods (Nolan 2002). Increased wildlife presence in urban areas indicated a dire situation for wildlife and the resources in their wild territories, and an increase in public awareness of drought and its effect on wildlife. It appeared from increasing instances of conflicts that severe habitat degradation forced wildlife to search for suitable food, water, and shelter in Arizona's cities.

In 2004, Arizona finds itself still trapped in the grip of ongoing drought, defined here as the deficit of precipitation as compared to historic average levels. Because of this, wildlife must cope with seasonal and lasting impacts of food and water shortages. Black bear contacts in metropolitan Phoenix as well as bobcat (*Felis rufus)* and mountain lion (*Felis concolor)* encounters in Tucson illustrate some of the searching behaviors that animals must resort to in times of resource limitations. The appearance of such animals indicates that habitat conditions in natural environments have reached a critical point. At this point, animals such as bears that are high on the food chain, and which normally have a range of foods available to them, have effectively run out of options and must search for new resources. While humans may view the presence of large mammals in cities as abnormal animal behavior, it indicates that normal habitat is degraded and that the animals likely are employing a strategy called optimal foraging to locate and claim the best resources (Bell 1991).

Although humans may be buffered from drought impacts because of the Central Arizona and Salt River Projects (Glennon 2002), which deliver constant supplies of water to our cities, wildlife feel the progressive negative impacts of low precipitation. Large animals could be considered to be buffered from immediate drought impacts to some degree, as first small animal, then herbivore, species decline. As drought severity and duration increase, even animals at the top of the food chain experience delayed impacts of drought through prey population declines and habitat degradation. Human alterations of the arid environment further stress many species, ever far from city development, by constraining animals' ability to migrate to available food, forage, or prey during drought. When animals do attempt to extend their foraging or hunting ranges, they can encounter human settlements and conflict can ensue.

Many factors combine to put stresses on wildlife populations: urban development, habitat degradation, water table reduction, riparian area loss, and the duration and timing of severe drought conditions among them. These factors fall into two categories: ecological changes due to climate fluctuation, and habitat changes due to human alteration of the landscape. This paper attempts to evaluate each of these physical stressors, and to show that in conjunction they severely inhibit many wildlife species' ability to survive and reproduce. In addition, the impacts of urbanization combined with severe drought may explain why animals that normally avoid human contact have willingly entered the hot, bustling metropolitan areas of Arizona's desert basin cities. As there are few peer-reviewed or even academic resources that address directly the impact of drought on wildlife, the system or reporting (or neglecting to report) contacts between

urban wildlife and humans, and mitigation possible to alleviate pressures on wildlife during drought, this paper draws on media reports, conference presentations, public websites, and unpublished Game and Fish records. It stands as a collection of reported and recorded impacts of drought on wildlife through case studies and anecdotes, and in doing so reports more human observations of drought impacts than biological, reproducible data on individual species. This is important to understanding how humans fit into the wildlife-habitat-water puzzle, however, since an overview of human perception of drought impacts on wildlife reveals how much awareness drought has pervaded everyday thought, and how much it factors into conceptions of wildlife.

The pressures that wildlife feel during drought are not only physical. In their wild habitats species may find fewer food resources, a direct physical impact due of drought. When they employ normal searching techniques to find food they often encounter human-constructed boundaries that limit their movements, or they find humans who are not amenable to wildlife behaving in ways that seem abnormal. Both of these impact population viability, and are indirect, often less quantifiable results of drought impacts. Identifying which events drought causes, versus which events are due in part to other climatic variations or natural events, such as fire or flood, is not an easy task. *Measuring* the multiple impacts of drought on wildlife, once they are identified, is not an entirely objective endeavor, either. Increased media and agency reports often reflect heightened societal concerns about specific events—such as bobcats in suburban developments—more than they indicate habitat degradation or declines in wildlife health. Such reports are most valuable as barometers of public perception of drought severity and wildlife species themselves, and function as records of the most extreme, visible signs of drought impacts on wildlife.

Most people become attuned to drought's effects the day that bears find their way into cities, or coyotes (*Canis latrans*) snatch a pet dog. Yet drought impacts on wildlife species, as on the ecosystem in general, are persistent and pervasive throughout the food chain. Impacts progress gradually, first affecting vegetation and individuals, then populations of small animals, and eventually moving upward through the food chain to large carnivores. Thus, highly mobile animals near the top of the food chain, particularly carnivores and omnivores, may experience drought impacts months or even a year or two after other populations of animals. This results in a "lag effect" not immediately attributable to drought (Figure 1). Like meteorological effects themselves, impacts work their way through the system. People often overlook or discount small signs of trouble, such as shriveled or brown cacti, and only realize the severity of the problem when the impacts directly and negatively affect their lives. For example, until mountain lions emerge on trails, few mentions of drought appear in the media; similarly, until reservoir storage and groundwater tables fall to levels that limit recreation or even personal water supplies, drought in our already arid environment seems to easily ignored.

Although the appearance of wildlife in cities does often indicate habitat degradation, long-distance animal movements may not be as unprecedented as we think. Wild habitat did not—and still does not—arbitrarily stop at our town lines. The appearance of large animals (especially those dependent directly on vegetation) in cities may represent an extreme in normal behavior. An elk may extend its search for forage 25 miles during drought, as compared to its usual range of 10 miles, for example**.** Humans usually contact wildlife managers when an animal seems to be a "nuisance," or if they perceive that the animal is a threat to their, their pet's, or their property's safety.

Many land management organizations and agencies attempt to prevent conflicts, for example by releasing educational information stating that "A fed bear is a DEAD bear." Visitors entering the Santa Rita Mountains (Coronado National Forest) receive a flier that states this and

offers precautions to humans who want to avoid attracting bears. Such fliers do not always work; in early June, 2004 a bear wandered into a Madera Canyon campground within the Coronado National Forest and ripped apart a tent. While the bear likely was attracted to food or human scents, a newspaper article reported, Arizona Game and Fish regional supervisor Perry stated that officers were forced to shoot and kill the bear, since "[c]learly the bear was unyielding…it's certainly not something we're going to put up with in an habituated animal" (Teibel 2004a). The media report also implied that the main problem was the bear's desperation for food due to habitat degradation, and paraphrased Perry's view that "there likely will be more bear encounters in the mountains around Tucson until the summer rainy season brings forth natural feed for foraging bears."

Strict enforcement of regulations or distribution of warning fliers to control human actions are not as practical in urban areas as they are in limited-access recreation areas such as a national forest. However, with urban wildlife specialists citing the eventual harmful or even fatal consequences for animals that become habituated to human contact, some cities *have* considered laws banning the feeding of wildlife (Associated Press 2003). In both protected and urban areas, animals habituated to or dependent on humans often pose a safety threat to people, so are killed or relocated. Because many people—members of the public and agency employees—oppose unnecessary killings, managers have tried to look for ways to stop the conflicts. Understanding how animals respond to drought, one of many possible stresses on populations, may allow for more proactive planning and public education programs, and fewer conflicts between humans and wildlife.

Desert animal physiology and water requirements

Contrary to popular opinion, not all species found in the Sonoran desert or other parts of Arizona are specially adapted to desert life. Many populations in the Southwest are genetically identical to populations in more temperate parts of the continent. Mountain lions, bobcats, and black bears, for example, share the same genetic makeup as their relatives throughout other parts of the Western United States and Canada. They did not, therefore, evolve genetic physiological adaptations to drought as did species that originated in the desert.

For other animals, especially those thought to have evolved in the desert, physiological adaptations confer survival advantages in an arid environment. For example, body size in some animals may be decreased by the desert environment. Whether this is due to genetic adaptation or to environmental constraint on growth is still in question; two theories attempt to explain the fact that some populations in deserts are known to be smaller than their relatives in temperate areas. The first posits that to achieve water balance, desert animals tend to have a decreased body size so their systems require less water. All animals' bodies contain 60 to 80 percent water by weight, and water lost must equal water gained. Bergmann's rule states that an animal's body size will decrease with an increase in environmental aridity, since a higher surface area to body mass ratio allows for greater heat dissipation, and therefore lowers water demand (Degan 1997).

While some scientists attempt to use genetics to explain differences in body size, others refute this by citing examples such as the desert fox. These populations tend to have smaller body sizes than their relatives in temperate zones, but do not often belong to different subspecies or species. A second possible explanation of reduced body size in animals such as the fox, summarized in a collection of studies in Degan (1997), is that many desert carnivores that appear to conform to Bergmann's rule may actually have a smaller body size due to prey scarcity or smaller prey mass. Thus reduced carnivore body size results from a caloric deficiency. The lack of suitable vegetation in a desert habitat may similarly constrain herbivore growth. This

explanation accounts for body size difference as a function of nutrient and caloric intake alone. It remains unclear whether smaller body size is a result of genetic selection, or whether nutrients and calories are so limited in desert environments that growth among successive generations is stunted.

Species that have evolved in the desert exhibit adaptations beyond reduced body size. Some small mammals, such as the Kangaroo rat (*Dipodomys deserti*), can concentrate their urine and excrete drier feces to minimize water loss, and some species can even tolerate the saline waters that remain in desert water holes after evapotranspiration. Many rodents spend weeks or months of extreme hot (or cold) periods in aestivation, a state of torpor which minimizes metabolic demand for food or water. Other small mammals, such as jack rabbits, have huge extremities such as ears and feet, lighter-colored fur, and a thinner coat to increase heat loss (Sowell 2001).

For species with no or few physical adaptations to drought, behavioral adaptations are vital. Many animals depend on free-standing water, shade in areas with abundant vegetation, or extra moisture available in plant leaves and roots. Animals that require free water generally have at least one of two capabilities: they can move long distances to search for water and/or they can store water. Large (non-carnivorous) mammals most often require frequent access to free water, particularly during lactation, and have developed behavioral adaptations to fulfill this need. For example, bighorn sheep occupy a set home range, but extend their search radius for food to more and more distant areas. The reproductive cycle of elk in Rocky Mountain habitats coincides with the spring vegetation growth, and animals move seasonally into mesic areas to enjoy increased cover and nutrients (Ager et al. 2003). In addition, during drought even ungulates such as mule deer (*Odocoileus hemionus)* and Sonoran pronghorn *(Antilocapra americana sonoriensis)* that are normally less dependent on free water have been shown to seek the shade and cooler temperatures that riparian habitats can offer (Ballard et al. 1997).

Without seeking cooler environments, wild burros theoretically can survive for as long as a week without drinking, but in the process lose as much as 30 percent of their total body weight (Sowell 2001). Long-distance migration or severe water and nutrient deprivation are extreme adaptations that represent temporary reactions to harsh drought conditions. While the adaptations may sustain healthy, adult animals, they may be too severe to allow young, reproducing, old, or high-density populations to survive. For species whose lives depend on their ability to adapt to the changing environment, population health varies with resource availability. Such species often experience severe stress and high mortality during drought, when neither searching nor storing water remain options. Some researchers think that the additional alteration of riverine habitat has eliminated a crucial source of vegetation, prey, water, and cooler temperatures that might otherwise allow animals to survive drought in desert environments (Schneider and Root 2002).

Even carnivores such as mountain lions and coyotes, which do not normally require water besides that obtained from the flesh of prey, feel the impacts of drought as vegetation withers and herbivorous prey species die. Coyotes become dependent on water during drought or stress, although they may have physical adaptations to mitigate effects of the hot, arid environments. Some desert canids have a higher panting rate, a lower heart rate, and a smaller body size as compared to canids in non-arid environments (Bothma 1998). During drought, coyotes have been known to dig holes in desert sands to find sub-surface water, which they visit repeatedly (Sowell 2001). Mountain lions, like coyotes, require more prey to fulfill their water needs during drought, but due to prey scarcity during these times also rely more on free water. Felids in arid African ecosystems normally do not need to drink water, but obtain as much as 50 percent of their moisture needs by drinking from pools and rivers during hot periods. They also

reduce overall water demand by resting in shady habitat during the hottest hours of the day (Bothma 1998).

Drought and human impacts on wildlife habitat

In the Southwest, animals have historically had to drastically alter their physical state or behavior due to the sustained, severe droughts and more frequent, less intense droughts that have occurred as part of a normal desert climate. Through tree-ring records, scientists found that the Southwest experienced several extended periods of drought before modern record-keeping began. In the Tucson, Arizona area (Climate Division 7), scientists can identify regular periods of severe dry conditions even before the instrumental record began in the late 1800s. Such periods include 1085-1094, 1245-1254, 1437-1446, 1662-1671, and 1776-1785. Instrumental records show that droughts of equal or greater severity have also affected the Southwest at least twice in the past century (CLIMAS 2002). Because drought is a normal phenomenon that has occurred—and will occur again—it is important to understand its effects on wildlife populations, especially as human and wildlife populations are pushed closer together.

The regular occurrence of drought makes it a normal part of Arizona's ecosystem, but means that animals must make drastic migrational or physical adaptations often. Additionally, some wildlife biologists estimate, some wildlife species will not experience relief from drought effects for as long as three years after a drought as the ecosystem recovers. Biologists therefore consider wildlife and the habitat on which they depend to be in or recovering from drought more often than not (Miller, Arizona Game and Fish Department, personal communication 2004). Thus, any negative effects we see, such as population declines, reduced reproductive success, and larger search ranges that result in increased human-wildlife conflicts in urban areas could be considered regular and ongoing issues, rather than anomalous problems.

To assess these impacts, wildlife managers separate stresses due to drought from those due to human action. Drought reduces available food, surface water, and vegetative cover, and decreases reproductive success and survivorship. By decreasing total effective habitat, or land that is connected and easily traversed, to smaller, discrete patches, isolation among metapopulations occurs. This isolation and restricted movement over time may further reduce reproductive success and normal movement. Normally, entire populations have redistributed themselves in search of resources; elk herds in Flagstaff shifted their ranges as much as five to fifteen miles in 2003, for example, probably as a response to declining habitat availability in their former ranges (Miller, personal communication, 2004). With increased human infrastructure, animals such as elk may find themselves unable to leave drought-desiccated habitats, or may find themselves relocating in what is now a city as they do in Flagstaff.

Human actions further exacerbate drought impacts, making normal wildlife adaptations to drought more difficult or even impossible to achieve. Humans, through groundwater pumping, have lowered the water table that supplies forage and trees with perennial water, and decreased the number and quality of surface water sources available to wildlife. In addition, the introduction of non-native grasses, trees, and other plants, as well as the conversion of land to monocrop farmland and rangeland for livestock grazing has eliminated many native plant communities. The construction of farms, cities, recreational areas, military bases, and roads has also decreased the amount of productive habitat for many wildlife species, as well as fragmented historic habitat and introduced barriers such as fences to normal paths of migration (Miller, personal communication, 2004).

The role of riparian areas in the Southwest and the changing Santa Cruz

While this paper looks particularly at urban encounters between human and wildlife populations, to understand the broader situation one must look beyond the city limits to wild habitat.

As explained above, many species—especially large mammals—control their body temperatures and reduce metabolic demand for food and water by moving to cooler habitat, or areas that offer reliable sources of free water or moisture-rich forage. Mesic areas, which are more temperate than the surrounding desert, include riparian (river or stream) areas, the habitat around artificial lakes and reservoirs, high altitude (at or above 4000 feet, approximately), and the northern or eastern slopes of mountain ranges, where temperatures are lower and moisture greater.

Human alteration of the environment has reduced the quantity and quality of many riparian areas. Ninety percent of pre-settlement riverine habitats have disappeared since extensive development, farming, and grazing began in the early 20th century (Glennon 2002, Grahame and Sisk 2002). Riparian areas function as main drivers of water, nutrient, and sediment transfers, and also play a crucial role in maintaining a functioning food chain (Schwartzman 1990).

While land along rivers and streams provides wildlife and vegetation habitat in many areas around the country, in the arid Southwest such areas are home to species that could survive nowhere else in the desert. Riparian obligates, including the Western red bat (*Lasiurus blossevillii*) and beaver (*Castor canadensis*) require broadleaf deciduous forests of willow (*Salix sp*.), cottonwood (*Populus sp*.), and sycamores (*Platanus sp*.) that only grow near water sources. Additionally, all fish species need the continuous flow of water itself (Arizona Game and Fish Department 2003). Obligates are often not highly mobile; while bats may have the ability to search for new riparian areas as rivers run dry, beavers and fish have no way to traverse miles of desert to find better habitat. As described above, non-obligates such as carnivores also visit riparian areas, and rely on free water and shaded habitat during hot summer seasons and drought.

Part of understanding urban human-wildlife conflicts comes through a review of the history of human alteration of arid lands. Riparian loss and degradation did not occur suddenly; rather, these processes have been occurring—and some may argue accelerating—for the past 60 years. The accumulated effects result in decreased available resources; humans and wildlife both attempt to use the remaining resources, which often results in overuse. Drought further reduces resource availability, so wildlife species and an increased number of people depend on declining habitat, in this case, a riparian area.

The following example shows how one riparian area became an urban metropolis unsuitable for the species that historically inhabited its shores. Similar situations unfolded in many riparian areas throughout Arizona and the Southwest, with negative consequences for wildlife pushed out of increasingly-urban habitat.

The Santa Cruz River, which flowed north through Tucson, was once a perennially-flowing, healthy river that supported a lush riparian corridor for diverse plant and animal species. Even during drought, Tucson usually enjoyed water supplies from this river and the Rillito, as well as perennial stream flow from the surrounding mountains (Glennon 2002, Minkley and Brown 1994). A traveler described the Santa Cruz in the nineteenth century as rich with "fish and

tortoises of various kinds." In *Water Follies*, Glennon paints a complete picture of the river: "Beaver, muskrat, and water fowl were common. On the upland areas, mesquite bosques [forests]…covered vast areas….[It was] a valley covered with poplar, willow, ash, oak, and walnut trees" (2002).

Much of this changed in the 1940s, a decade of decline for the Santa Cruz and many other rivers, for two reasons. First, although population growth had occurred since the early part of the century, it now reached levels that surface water supplies could no longer sustain. Second, mechanical means of drilling wells and extracting water allowed people to tap into deep groundwater aquifers for the first time (Glennon 2002).

Perennial rivers and streams in the Southwest depend on a water table one to two meters from the surface (Minckley and Brown 1994). Before groundwater pumping, the 140,000 acre-feet of water added annually to the Tucson aquifer through snowmelt and rain overwhelmed the aquifer's capacity, and the river ran. After pumping commenced, however, the Santa Cruz became a "losing" river, so called because water flowed away from the river to the aquifer below. Once the water table dropped below the river bed level, there was little hope of restoring the perennial flow (Glennon 2002). Fish and other riparian obligates could not survive in the ephemeral Santa Cruz any longer, and gradually, because the water table dropped, the roots of surrounding stands of trees could not reach any moisture. Secondary effects of groundwater pumping included not only the die-off of aquatic animals and plants, but also the destruction of the forest habitat that so many other wildlife species used for shelter as well. Other rivers in the Southwest within *and* far from urban areas suffered a similar fate.

Searching behavior

When resources decline in an animal's home range or territory, it moves to whatever extent possible to areas of better resources using a strategy called "optimal foraging." This strategy includes locating and claiming the patch with the highest concentration of or the best resources, and fully utilizing the resources within a given patch (Bell 1991). In the past, wildlife may have moved from one mountain range to another along riparian corridors. Thus, populations dispersed from one "sky island" (high-altitude, mesic habitat) to another.

Today, the searching behavior of many species has not changed, but the landscape within which they must search has. Instead of encountering the lush Santa Cruz when extending its range from the Santa Catalinas, for example, a bear whose mast crops had failed would instead find itself wandering through foothills developments. Bobcats and mountain lions used the optimal foraging method of vastly expanding their territories after the Aspen fire reduced prey species on Mt. Lemmon. In their search for more prey and territory, however, they encountered high-density human settlements with new sources of prey: small pets and pet food left outside.

Many animals have—or in drought stress do—opportunistically forage on human-supplied resources, as an extension of the optimal foraging strategy they normally apply. Normal searching behavior, particularly the extended search radii that may result during drought or after wildfire, can lead to wildlife encounters and conflicts with human populations. As Arizona's drought persists, its cities have seen an increase in contacts with large animals otherwise rarely seen near human developments.

Case studies

Urban wildlife and drought

Humans disproportionately choose riparian (or former riparian) areas for their own habitats, and enhance this land with native plants, lush grass, and standing water. This sets the stage for conflicts when animals follow washes from wild areas into cities and find abundant resources. The location of most urban areas along rivers or in riparian zones is logical from a human perspective, as these areas have historically conferred a slight increase in resilience to drought. However, the physical presence of the urban area, with its traffic, bank channelization, and large population limits wildlife accessibility to remaining river habitats. It also introduces a physical barrier to wildlife species that normally move to or through desert basins to find food and water sources. Restricting wildlife movement contributes to decreased options for species, and can be a factor in increased mortality during drought or other periods of stress (Bright and Hervert 2004, in press).

The ecological roles that native habitat and urban areas play in animal lives has changed, and urban developments may increasingly function as mega-riparian zones by offering oases of food, water, and cover amidst resource-poor arid areas. Coyote, fox (*Vulpes spp.),* skunk (*Mephitis spp.),* javelina (*Peccari tajacu*), and several squirrel and bird species are only a few of many animals that live in or near resource-rich urban areas. They frequent parks, residential areas, washes, golf courses, and other places that offer maximum cover and minimal contact with humans. Often, these animals forage most during night hours, as did urban coyotes using recreational areas and washes in a Tucson, Arizona study (Grinder and Krausman 2001). In northern cities, large animals such as elk have established permanent residence in urban areas, including golf courses, parks, and yards in Flagstaff (Lee and Miller 2003). Other animals, including bear and mountain lion, become "urbanites" only in extreme cases.

Five case studies below illustrate the severity and frequency of the continued conflicts between human and wildlife populations, both for the health of wildlife species and the public perception of wildlife as worthy of protection and reverence.

1) Mountain lions in Sabino Canyon, Tucson, Arizona

Animals that pose a potential threat to human life receive more public attention than do other species, and therefore their presence can bring the issue of drought into the forefront of public concern. The example of mountain lion presence in the Sabino Canyon Recreational Area, part of the Coronado National Forest in the Santa Catalina Mountains near Tucson, illustrates how people react viscerally to predators even when there appears to be a reason, such as drought stress, for their presence. Often people do not notice progressive, compounded impacts of drought on habitat surrounding their urban area until a "crisis" such as a dangerous encounter with a mountain lion occurs. Figure 1 illustrates the multiple scales of impacts that result over time from a precipitation deficit. A large carnivore such as a mountain lion would feel drought impacts after prey species, which were dependent on vegetation, which was dependent on precipitation, declined. This reveals that humans do not necessarily notice—or care about—drought impacts that do not personally threaten their lifestyles, and also that until wildlife species confront humans in "human territory," an urban lifestyle makes it easy to ignore the subtle, yet compounded, impacts of drought.

The case of mountain lions in Sabino Canyon shows the progression of media and public attention to drought, and the gradual shift in public perception of the lions. Mountain lions in low

elevation habitat may have been merely responding to prey scarcity due to drought, fire, or other undetermined condition. Yet some members of the public, encouraged by media reports that portrayed this behavior as "abnormal," and thus frightening, eventually saw the animals as bloodthirsty, stalking predators. This distinction makes a drastic difference in people's perceptions, and it does for the lions' lives. In this case, drought may have contributed to a larger hunting range; however, the near-hysteria, legal worries, and passionate debates over animal rights that ensued illustrated that another component to the perceived problem was an ingrained fear of large predators themselves.

Most Tucsonans followed the spring, 2004 story of the mountain lion sightings and subsequent hunting, capture, and killing in Sabino Canyon. Many also passionately defended polarized views opposing or supporting the hunts. Tucson newspaper archives contain over 1,500 articles about the mountain lion controversy, indicating that urban wildlife captured the attention of media, the public, and wildlife managers. The link between drought and the mountain lion presence seems tenuous, yet remains one of several explanations for the aberrant behavior.

Approximately 2,500 mountain lions live in Arizona, according to Coronado National Forest officials (Lowe 3/10/2004). They "are primarily nocturnal, shy, elusive, and solitary, except during the breeding season," says a Department of Agriculture information page (State of California, accessed 2004). Their territories and search ranges vary by season and sex. The arrangement of home territories for a population of mountain lions depend on many factors, including the "social and reproductive status of animals monitored, the quantity and quality of the habitat, elevational migrations of prey, and [mountain lion] density….[as well as] energy requirements [and] the mating system" (Logan and Sweanor 2000).

Juvenile males are "transients," wandering and expanding existing range in order to establish their own home ranges of up to 100 square miles, while females tend to maintain a more constant, smaller territory of 20 to 60 square miles (Logan and Sweanor 2000, State of California, accessed 2004). Additionally, during breeding season females travel shorter distances and less frequently than they normally would (State of California, accessed 2004). Conflicts between humans and mountain lions often involve juvenile lions that roam beyond the traditional boundaries of lion territory or protected areas to establish their own ranges. Other conflicts may result from prey scarcity in regular territories, which forces the lions into lower elevations and results in possible contact with humans.

Mountain lions are not new residents in Sabino Canyon or Mt. Lemmon, and humans have had a long, changing relationship with them for centuries. Lions have been hunted for decades, first vehemently during predator-elimination campaigns in the late 19th and early 20th centuries, and more recently as game populations. Hunting restrictions differ from state to state. In California, for example, lions have been specially protected since 1990, and voters rejected a ban on hunting in 1996 ("Proposition 197" 1996). In Texas, people can hunt the animals without restriction, as the mountain lion is classified as a, "non-protected, non-game species" (The Mountain Lion Foundation of Texas 2004).

The first reports of a "fearless" mountain lion appeared in Tucson newspapers in November, 2003. According to the newspaper report, "Mountain lion roaming in Sabino Canyon," the animal had been spotted a "half-dozen times in recent weeks and appear[ed] to show no fear of humans" (Allen 11/13/2003). Animals showing a lack of reticence toward humans or activity near public areas during daylight hours had been responsible for past attacks, so managers often use this type of behavior as a predictor of potential conflicts. Ranger Raley, of the Santa Catalina District, said in the same article that, "Big cats are not uncommon in desert

mountain areas…but some reports indicate that this cat is not shying from humans as we would expect." The report also gave readers advice from wildlife biologists on proper actions to take in a mountain lion encounter. Later articles quoted wildlife managers as saying that 30 mountain lions had been sighted in the past few months, which indicated there might be a public threat.

Little more about the mountain lions appeared in the media until February and March, 2004. Then, following more sightings of "fearless" mountain lions in popular recreation areas, articles such as, "Lion worries could shut part of Sabino Canyon" appeared. Ranger Raley, previously satisfied with mitigation efforts to increase public awareness, now stated that, "This has gotten to the point where I believe we need to do something" (Lowe 3/09/2004). While the recreational area remained open, rangers distributed more safety tips to Canyon visitors, and began actively considering ways to remove mountain lions from Sabino Canyon. For the first time, they also began to evaluate which areas, if any, should remain open to the public in the future.

After the issue reached the public, it received media attention daily. The day after the announcement that wildlife management agencies had considered removal of mountain lions, the Tucson Citizen published an article that further fanned the flames of controversy: "Sabino lions solution: kill them" (Lowe 3/10/2004). In the article, Arizona Game and Fish biologist Whetten defended the policy to actively hunt and kill the roaming lions, saying that, "'We simply cannot take the chance of relocating and releasing a mountain lion that constitutes a threat to humans….[N]ot when lives are at stake.'"

Due to increased public concern following a mountain lion attack in California, which resulted in the death of a mountain biker, managers closed Sabino Canyon until they had could control the three to four lions they perceived as problem animals. Daniel Patterson of the Center for Biological Diversity advocated non-lethal options for the aggressive lions, and stated that killing or removing the animals would likely only be temporary solutions, since new lions would re-establish territory in their place. He also reported concern that "'new lions would lose their fear of humans as well'…[and stated that the] 'Forest Service has to learn to better manage visitors, or it will have to keep killing lions'" (Lowe 3/10/2004). This comment struck at what many isolated as the core of the issue: do we manage humans or wildlife in protected areas?

Finally, following a public meeting on March 16, 2004 concerning possible hunting and destruction of the mountain lions, the Arizona Game and Fish Department announced their decision to continue with their plans. Opponents offered criticism of and alternatives to the policy to kill the mountain lions, but Game and Fish officers eventually rejected them as not practical, or not protective of the state's liability in the case of an attack. Some Tucson residents wanted increased public education before lion destruction. Said one, "We can't educate lions, but we can educate people about lions. Education is what's needed, not shooting" (Young and Cedillos 3/15/2004).

Mountain lions apparently retreated into higher elevation, rugged areas, and after five days of searching, Arizona Game and Fish managers announced an end to the hunt. Newspapers on March 29 announced that, due to costs of up to $6,000 a day, the **"**Sabino hunt for mountain lions ends indefinitely," and the area would open to the public again (Innes and Stauffer 3/29/2004). Still, Game and Fish officials did not end all efforts to locate the lions. In early April, managers captured a mountain lion in a wash near a foothills school, and airlifted the 80-pound, two to five year-old female to a rehabilitation center in Scottsdale (Nolan 2004).

Attention to the issue of mountain lions waned after the capture, until a lion reportedly stalked a man and his dogs at his foothills home in late April, and became prominent again in May when two men bicycling down Mt. Lemmon reported using rocks to pelt a small female that they said had chased them (Teibel 2004b, Pitzl 2004). The article about the attempted dog attack emphasized the importance of eliminating attractions such as pet food and small pets to lions, because animals roaming into the urban fringe may do so in search of food. The mountain lion that stalked the two mountain bikers also reportedly stalked wildlife managers who went to assess the situation a day later, and who shot the lion on sight. A 70-pound, 18-month old female, the lion apparently had shown little fear, and acted abnormally by appearing in daylight near humans. Whether drought stress, fire-induced habitat and prey degradation, or even record-high April temperatures (or some combination of these factors) were to blame is unknown. Managers are left to wonder, "what caused this fatal encounter, and the scare five weeks earlier when mountain lion sightings increased in Sabino Canyon" (Pitzl 2004)?

2) Black bears in metropolitan Phoenix

Mountain lions were not the only large carnivores worrying Arizona's city-dwellers. Black bears also came into close contact with humans, and during the exceptionally dry year of 2000, dozens entered metropolitan Phoenix. "Bears have left Arizona's mountains and headed for the cities, drinking from swimming pools and hanging from trees in the booming suburbs that are pressing closer to the animals' homes," one newspaper report stated (Thomas 2000). Arizona Game and Fish Department documents listed winter 2000 as "the driest on record…[m]ost food crops that bears depend on failed—these included acorn, manzanita berries, elder berries, and pinyon nuts; in addition, the prickly pear fruit crop failed almost entirely" (Shroufe 2001). In dry years, bears and other species depend on the fleshy pads of prickly pear; only in the most severe droughts do these become desiccated as well. The increased number of conflicts suggested that bears, which are not adapted to desert basin conditions and which normally avoid human contact, had increased their range in search of food. Mast conditions in nearby mountains were poor, and deer and coyotes were reportedly dying of starvation that season ("Bears in Phoenix" 2000).

"It was the unavailability of food that forced the bears to wander in search of food, and some of them inadvertently ended up in the [Phoenix] Valley," said wildlife biologists (Thomas 2000). Reports of urban bears began on August 11, 2000, and ended on January 4, 2001. In that time, wildlife managers handled 50 separate reports of bears in Phoenix (up from a normal one or two encounters every few years (Schenk 2001)), and 130 bears throughout Arizona. Due to severe dehydration, about a third of the animals went to rehabilitation centers for advanced health care.

In the Tucson area, media reports blamed decreasing bear habitat on growing human populations. Urbanization and a population that grew 2.4 percent between 1999 and 2000 alone "makes more friction between bruins and people inevitable," said one media report (Vanderpool 2000). In addition, inexact bear population estimates limit management, and population control happens only after a crisis event. Concern about individual species peaks and wanes. In 2004, mountain lions seemed to pose a major threat to recreating Tucsonans, but seemingly forgotten were the "people-eating" black bears that threatened the city following the Mt. Lemmon attack on Anna Knochel in 1996, as Vanderpool's article recalled. Interestingly, the bear attack occurred in another extremely dry year, when animal and human populations may have come into more frequent contact. In both the mountain lion and black bear situations, the state uses indications of abnormal animal behavior—due to drought, disease, or urban stress—as rationale for destruction.

The June, 2004 shooting of a black bear in Madera Canyon comes at the driest time of year, in the midst of a prolonged drought in the Sonoran Desert. This case seems to illustrate the warning signs that managers look for in identifying a potential conflict: repeated, deliberate contact with humans, and finally an act of apparently unprovoked aggression toward people. Ultimately, some situations that end in managers shooting bears or mountain lions are financial issues as well as safety concerns, since the Forest or Park Service must reduce the risk of prosecution if an attack were to occur.

Bears sometimes have an advantage that makes them less of a "predator" in many people's eyes. Because degraded habitat and failure of mast crops are visible impacts of drought, encounters may be more predictable than they are for mountain lions, animals that depend on discrete populations of unmonitored small prey. If humans perceive that bears and other predators are searching for food (in the form of non-humans), they may have more empathy for the species, even when the bears are involved in conflicts with people. While mountain lions are only attracted by prey—other wildlife, pets, or children, some would fear—omnivorous bears come "benevolently" in search of garbage, pet food, fruit trees, and other food sources. The less lethal actions toward bears in Phoenix may be due to public perception of the animals as less life-threatening.

3) Media reports indicating increasing wildlife in urban areas

Interspersed with the front-page stories of bears and lions are more frequent accounts of bobcats, coyotes, javelinas (collared peccaries), and even smaller animals such as skunks in urban areas. While numbers of encounters with these animals are actually higher than those with large animals, they receive less media attention and much less public notoriety. Whether this is a function of these animals' lesser threat to humans, or of their low-density, habitual presence on the urban fringe remains unclear. Either way, besides the extreme contacts described below, people tolerate the presence of these and other animals more than they tolerate predators, especially during drought. Some foothills residents actively attract such animals, leaving pet food out for coyotes and javelinas that might come along. For wildlife already near the urban/wildland border, increased habituation to cities and humans may be an ongoing process, accelerated as much by urbanization as by drought stress.

Media reports sometimes incorporate both climate influence and urban expansion into explanations for animal encounters, but fail entirely to mention the impact of media actions in perpetuating the issue of urban wildlife "problems." As in the case of the mountain lions and bears, encounters where human life or pets are threatened may garner special attention and misrepresent actual drought impacts on wildlife. Relying on news accounts may also provide a distorted count of conflicts, since media reports beget more reports. Species such as coyotes, skunks, and bobcats that frequent urban washes and parks may be more visible during drought, but people are also more likely to report sightings if the issue is prominent in the media. During extreme drought conditions, significantly increased reports about urban wildlife probably do indicate a link between habitat degradation and species' willingness to enter densely-populated areas. However, levels of "normal" wildlife presence in non-drought years, which could act as a baseline for comparative purposes, has not been accurately represented since reports decrease when drought or conflicts are not a top story.

In Prescott, residents reported a virtual parade of mountain lions and bobcats moving through the dry washes behind homes in 2002. Media reports link "a moderate to severe…statewide drought…[which] has not only drained lakes and reservoirs" to "bears and mountain lions…penetrat[ing]farther into cities [to] hunt during daylight hours" (U.S.A. Today

2002). The same report quoted wildlife biologist Aikens as saying, "'During dry conditions our arroyos and canals become superhighways for wildlife….You have coyotes sighted in downtown Phoenix and young mountain lions who are being kicked loose into the Prescott area to establish their own territory.'" While reports differ as to when the drought officially began, U.S.A. Today reported that 2002 was the fourth year of severe drought, and added that "the drought has been especially severe in northern Arizona, where this was the driest fall and winter in more than 100 years." Wildlife living in the typically moister, more temperate northern areas of the state may experience severe stress, as they have not adapted behaviorally to frequent water shortages.

In some cases, urban areas may attract animals with easy-access to prey, as seemed to be the case in summer, 2002, when coyotes snatched pets out of fenced backyards in the Phoenix valley. Wildlife biologists emphasized that this behavior was not necessarily aberrant for the coyotes and bobcats involved, but that search range may be larger due to drought impacts on food supplies, and development of normal feeding grounds. Yarchin, of the Game and Fish Department, stated that "Food, shelter, water and space are the requirements for any creature, whether human, animal or snake…. Drainages and washes lead them into the city - it ends when they find the golf courses and the bunny rabbits" (Nolan 2002).

Cases that alarmed urbanites most involved direct threats to children and pets. Mesa residents panicked when a father "found a coyote grasping his child and attempting to remove him from the house" ("Toddler Bitten" 2000). This represents abnormal behavior, and even the impacts of drought do not entirely explain the desperation behind this act.

Wildlife managers gave residents tips to mitigate incidence of coyote and bobcat encounters in their neighborhood, including reducing food sources or free access to pets and children. Since cities had become an extension of hunting grounds, it was vital to make the urban area a "resource poor" patch. In Mesa, Lake Havasu City, and Tucson, managers told urbanites that "feeding wildlife often leads to wildlife/human conflicts and…results in the destruction of the habituated animals. Coyotes and other animals are often quick to associate humans with food and become increasingly bold and troublesome" (Hall 2003). The same article emphasized that in many conflicts, "the animals are not the nuisance," and quoted Lake Havasu City Game and Fish officer Dickson as saying that, "'I attribute [the conflicts] to negligence….The coyotes are not the problem, the people are the problem.'"

4) Indirect effects of drought—fire-impacts on wildlife

While drought directly eliminates food sources, it also indirectly impacts wildlife when drought-induced wildfires destroy habitat or dam rivers with silt. Media reports in summer, 2003 blamed increased bobcats in Tucson on the previous season's Aspen fire, which burned 85,000 acres of habitat. "Fire-displaced animals become 'common' sight," declared a Tucson Citizen headline (Morlock 2003). The article continued to explain the relation of habitat loss, prey scarcity, and lack of vegetative cover to increased sightings of many wildlife species in urban areas.

A young bobcat treed in a Tucson apartment complex likely was one of many animals displaced during the Aspen fire. While urban bobcat populations do exist, according to University of Arizona Wildlife Biology professor Shaw, the Aspen fire forced more animals into suburban areas in search of food or habitat. '"The wildlife left the mountain for the same reason people did…[and] eventually, they'll go back up to the mountain when stuff starts growing again,"' said Shaw (Morlock 2003).

A Tucson-based wildlife control company, "Animal Experts," reported more calls concerning bobcats in 2001-2003 than it had in the previous five years combined. Increased sightings could be related to the bobcats' search for food, water, and shelter, particularly following the drought-related Aspen fire on Mt. Lemmon, and could be due to multiple people in the same neighborhood reporting the same incident. They could also reveal the intensification of problems due to city expansion, wildlife managers said ("Tanque Verde bobcat caught" 2003). In cases of fire-displaced wildlife, managers often expect that as habitat improves animals will return to wild areas, without human intervention.

5) Increased wildlife during drought, or decreased wildlife during wet periods?

Large animals, although most visible, are not often the species most sensitive to drought. Bears may wander into cities because they are following washes, prey, or forage to lower elevations, and also when habitat is severely and broadly degraded due to drought, fire, disease, or human alteration. Other animals enter cities more regularly; if we looked more closely, or counted, urbanites would see an increase in small animals such as mice, rats, raccoons, and other species less able to move long distances to new food sources. These animals might actually appear in peoples' yards years before bears and bobcats, in earlier stages of drought.

One of the most notable species whose numbers increased in Tucson during past drought years is the skunk, according to records of reported contacts with the animals. The reports do not, however, reveal whether overall skunk populations increased during the year studied. Typically present in low densities in many urban and suburban areas, skunks also inhabit the washes and parks of desert cities. However, during recent periods of resource scarcity, urban residents in Prescott and Prescott Valley, as well as Tucson, have encountered more of the "opportunistic feeders." Because they eat a wide variety of things, from fruit to eggs to small animals, wild animals find that urban areas offer a diverse buffet. Simply reducing attractants such as pet food, small pets, ripe garden fruits, and garbage would decrease the appeal of residential areas, say wildlife biologists, and force the skunks to search elsewhere for suitable food sources ("Homeowners" 2002).

While most people accept that drought negatively impacts many wildlife populations, and anecdotal evidence implies that drought leads to increased urban conflicts, only one study (Zack et al. 2003) has shown a link between increased wildlife presence in human-developed areas and climate variation. Zack et al. concluded that encounters between black bears and humans in a resort community in New Mexico were linked to the dry phase (La Niña) of ENSO (El Niño Southern Oscillation). Between 1982 and 2001, encounters occurred 4.7 times more often during La Niña (dry) years than during El Niño (wet) years, and 4.4 times more often than during median (normal) years. Black bears expand their ranges to search for food, the authors wrote, and fluctuations in food supply may be the cause of increased encounters during less productive, dry years (Zack et al. 2003).

A preliminary statistical analysis of urban wildlife reports collected by Wildlife Services (agencies such as "Animal Experts") showed that links between frequency of human-wildlife conflicts and drought conditions in Tucson varied considerably by species. Each year, Wildlife Service businesses are required to turn in an annual report to the Arizona Game and Fish Department, which oversees licensing and monitoring. These reports provide detailed information about the number of reported conflicts that occurred in the Tucson metropolitan area, the animals involved, the location and date of each incident, and the action taken to remedy it—often either release of the animal in a new area, or destruction of the animal. CLIMAS researchers entered 1,979 individual conflict reports into a statistical software program, and

grouped the data by year reported. This provided the opportunity for a broad statistical analysis using multiple linear regression, although ideally the data will also be analyzed at the daily or monthly scale for closer trend analysis in the future. For this analysis, species were coded as belonging to one of 13 groups of animals: bat (*Chiroptera sp*.), bird (raptors to passerines), bobcat, coyote/fox, javelina, raccoon *(Procyon lotor*), rat (*Muridae sp.),* rodent (gopher and mouse (*Pappogeomys sp),* skunk, small mammal (ringtail cat and badger (*Bassariscus astutus,Taxidea taxus),* snake (many species), and squirrel (several species).

Several precipitation and temperature datasets described general climatic trends within a year. Explanatory variables that may affect conflict numbers included average cool and warm season temperature and precipitation data. Total warm and cool season precipitation (in millimeters, mm). and average warm and cool season temperatures (in degrees C) were calculated from National Climate Data Center historical temperature and precipitation records for Tucson.

Winter precipitation is recognized as being more important for vegetation, water supply, and overall habitat health than precipitation during hot summer monsoons, since it is more gentle and evenly distributed (Pagano 1999). In addition, most of cool season precipitation soaks into the ground, rather than evaporating, due to cooler winter temperatures. In this study, cool season included months where the mean temperature in the 1948-2003 record did not exceed 15.56 degrees C (60 degrees F), which were January, February, March, November, and December — and "warm," April through October. While there is a high probability of receiving precipitation during each month of the cool season, the warm season encompasses the dry spring, in which little to no precipitation occurs, and the monsoon season, in which heavy rains are expected almost daily.

Overall results apply to the past 11 years (approximately nine of which have been in drought) in the Tucson metropolitan area. Cool season precipitation and temperature had the greatest influence on conflict numbers (Table 1); seasons with greater rainfall and temperatures during the months of January-March and November-December had decreased numbers of reported conflicts.

Reported conflicts for all species (total conflicts) decreased three times with each 4 mm. increase in cool season precipitation; this relationship was ecologically significant in explaining a trend, but was not significant at the 0.05 level.

Mammal conflicts (all species with bird, snake, and amphibian/lizard removed) also decreased significantly as cool season precipitation increased, and less significantly as cool season temperature increased. Mammals may also be more likely than birds and lizards to frequent the urban area, and to be reported as "problems," especially if they are large or enter homes. Increased numbers could also reflect a greater dependence on cool habitat and convenient urban food resources during drought.

For most individual species—including bat, bird, bobcat, javelina, raccoon, rat, rodent, small mammal, snake, and squirrel—conflict report numbers did not appear to be related to the climate indicators included in this model. Whether this result reflects actual conflict numbers or simply a lack of reporting for those species is not discernable from the available dataset.

Coyote and fox conflict reports decreased very slightly in years with more winter (cool season) rains, illustrating the subtlety of climate impacts on some desert species. Perhaps during wetter periods coyotes and foxes could thrive in wildlife habitat, or remain in urban washes rather than extending their foraging ranges beyond to backyards and city streets.

Three climatic factors influenced skunk conflict reports; conflicts decreased with increases in cool season and warm season precipitation, and with an increase in cool season temperature. Skunks, coyotes, and foxes often occupy or forage in urban environments, seeking the cool temperatures and resources available in washes, parks, and residential areas. It seems that they may seek water, shelter, or food in urban areas during dry periods, but apparently are better able to meet their needs in the wild during wetter, warmer winters. Thus, maybe drought conditions do not force animals into urban areas as much as the lack of drought conditions allows common "urban dwellers" to leave the city. Since no large animals were included, these results are insufficient to conclude whether drought caused bears, mountain lions, and other animals in habitats far from urban areas were more likely to venture into cities. It did, however, indicate that changing habitat conditions in the city did impact some populations.

Amphibians and lizards were the only individual non-mammal group to exhibit a strong decrease in conflict numbers in response to increased cool season precipitation. Since amphibians and lizards were grouped early in the analysis, it is not possible to separate effects climate may have on either amphibians or lizards alone. Increased precipitation during winter, for example, may have decreased amphibian conflict, while warmer temperatures during the cooler winter months may have allowed lizards to remain in exposed areas far from human habitation. Sample size for amphibians and lizards is low, so any results may not be representative of either population in the Tucson area. Since this was an observational study, predictions as to future responses of wildlife to drought could be made speculatively, but should not be used for planning purposes or applied to other areas or species.

Overall, other factors may be influential in increasing reports of wildlife conflicts. Over the past 11 years, conflicts appear to be increasing (Figure 2). Yet report numbers alone do not reveal how many animals actually entered urban areas, and since the data is aggregated at an annual time scale the timing of the reports is not obvious. An increase in reports could also be due to more wildlife service agencies in business to receive calls, more public awareness of wildlife (especially in coordination with increased media reports about wildlife stress due to drought), and increased urban development.

Future work, as mentioned above, may allow researchers to focus on a shorter time scale to look at conflicts grouped at a monthly or even daily level. Researchers may attempt to map the spatial aspect of increasing conflicts by geocoding available addresses of individual conflicts, which could separate the impacts of drought stress and development encroachment on the incidence of contacts.

Game animals and drought

Many—in fact, most—animals in Arizona do not live near cities, and their efforts to locate resources during drought often go unnoticed. The impacts of drought remain undocumented for most, as do the rates of mortality related to the timing of rains and heat waves. Two groups of animals—due to humans' special interest in them—receive more attention: game animals and endangered species (discussed in next section).

Wildlife managers often monitor populations of game animals more closely than other populations, since the fluctuations in numbers determine how many hunting permits agencies issue to the public. In Arizona, recent decreases in numbers of permits reflect wildlife population declines due to drought. For example, the number of deer hunting permits has steadily declined

for the past 15 years (Figure 3), and due to "prolonged drought" the Arizona Game and Fish Department issued the lowest number of permits in 2004 that they had since 1946 (Lee 2004). Future deer populations may increase, since fawn recruitment improved in 2003. However, big-game supervisor Brian Wakeling added that, "'large-scale population improvements [of white tail and mule deer] over last year's low level - which resulted from a record drought - have not occurred'" (Hajek 2004).

Antelope, bighorn sheep, and elk permits also have decreased in recent years. An Arizona Game and Fish Department posting reported conditions in 2002 as very poor: "we have just experienced one of the driest winters ever recorded. There's no relief in sight. Habitat conditions are poor. Our recent…surveys indicate that elk calf numbers are down significantly in most herd units." That year, total hunting permits decreased by 5,495 from 2001, and "hunter days," or total days a single hunter can spend in the field, increased to allow more "hunter satisfaction" (AGFD 2002).

Tree squirrel populations have also declined due to drought, as evidenced through declining squirrel-hunt success rates. Different squirrel species depend on different resources; while Abert squirrels (*Sciurus aberti*) search for moisture-dependent fall mushrooms, gray squirrels "prefer riparian corridors of sycamore, walnut and ash," and red squirrels inhabit spruce-fir habitat ("Hunting" 2003). Thus, depending on which habitats drought most impacts, certain types of squirrel populations will decline based on resource abundance and health. Since the northern part of the state was hit hard in recent drought years, gray squirrel populations along the Mogollon Rim may have experienced drastic population declines.

During drought, it is difficult to come to a conclusion as specific as, "Species X is declining due to a 10 inch precipitation deficit." Certainly, that would make drought impact assessment simpler. However, across Arizona wildlife species live in varied environments, from pine-covered mountain slopes to desert scrub. Drought impacts themselves are variable across the state, as well, depending on topography, elevation, and local water sources. In desert basins, vegetation dries out quickly and easily as ground water and stream levels drop. In mountainous areas or rivers near a steady water supply, plants may not feel immediate effects of drought since shade limits evapotranspiration, and a more stable water table prevents desiccation.

As seen in the 2003 hunting advisory information on the Arizona Game and Fish Department website (http://www.azgfd.com/h_f/hunting_units.shtml), individual species can be in "abundant" condition and "poor, declining" condition in the same season. For example, quail populations on the Mogollon Rim were increasing from previous years' low populations. In the Southeast corner of the state, however, quail did not receive precipitation during their breeding season, or following an already scant hatch.

Overall quail hunt records, kept by private hunters and posted online, offer a glimpse into the sensitivity of bird populations to minute changes in precipitation and also into the details with which hunters monitor weather and population dynamics. One private hunter notes repeatedly the link between discrete periods of rainfall and grasshopper hatches, which directly lead to increased survivorship of quail hatchlings. As an example of the links noted between quail population and climate fluctuation, the hunter's log reads, "We received a nice, slow soaker with a winter storm in March followed two weeks later by isolated, scattered showers. New green shoots are evident in most areas, especially filaree sprouts, a favorite spring green of Gambel's which provides Vitamin A to begin the reproductive cycle" (Quail report, April 2000, Globe, AZ, http://personal.riverusers.com/%7Ercorley/). The differential between drought impacts across the state and for various species emphasizes the difficulty of summarizing—or managing—wildlife

populations. Like climate itself, most populations fluctuate over seasons and between years, maintaining an overall sustainable population.

Endangered species and drought

Although most endangered species live outside urban and suburban zones, human actions in developed areas significantly impact habitat, such as that required by Sonoran pronghorn. The pronghorn survive in extremely low numbers of older animals and are subject to a high rate of predation, which also play a role in determining their general mortality and vulnerability to stress. Despite the fact that over 80 percent of Arizona's Sonoran pronghorn population, already extremely low, perished in the extreme drought conditions of 2002, public awareness of these impacts remains low (Bright and Hervert 2004, in press).

While drought effects such as reduced free water and total lack of forage alone could constrain the pronghorn population, human road development, groundwater pumping, and barriers at the U.S./Mexico border have exacerbated the decline of the surviving U.S. herd. As of the last population survey in spring, 2004, only 21 animals remained. Artificial water tanks in the animals' main Arizona habitat, the Organ Pipe Cactus National Monument, may have helped the pronghorn to survive during 13 months without precipitation; even these, however, would not have sustained animals beyond a certain length of time as forage was overgrazed and desiccated as well. Sonoran pronghorn in the United States have an additional challenge to overcome, because highways edging the monument prevent movement to natural water sources that the animals historically used during drought (Krausman, personal communication 30 March 2004).

For pronghorn and other animals that breed only once a year, timing of rains and number of days between last late-spring and first late-summer (monsoon) rains are crucial for recruitment of young. Pronghorn fawn recruitment is inversely correlated to the number of days between spring and summer rains ($R^2 = -0.72$, $P = 0.02$), according to a recent study by wildlife biologists at Cabeza Prieta. In addition, fawn survival is positively correlated with amount of winter rains ($R^2 = 0.69$, $P = 0.06$), but is not related to heavy, yet scattered, summer rains (Hervert, Arizona Game and Fish Department, personal communication 2004). In years of very low precipitation, and subsequent vegetation scarcity, female Sonoran pronghorn may not be able to reproduce at all, or may not be able to lactate enough to raise their young. What Hervert found encouraging was that very little of the overall habitat had to receive rain to improve Sonoran pronghorn survival, since the animals are highly mobile and do not overgraze a single resource patch. Forage enhancement programs may offer managers an additional tool, along with water tanks in the wilderness, to help the endangered population grow.

Responses to human and drought impacts—wildlife waters

Not all of drought-induced or human-accelerated environmental changes have occurred without notice or concern among wildlife biologists. Some wildlife managers have worked to mitigate the effects of drought in general, and the effects of cattle grazing and water diversion on endangered species such as the Sonoran pronghorn, in particular, since the 1940s. To lessen the impacts of riparian loss and habitat fragmentation on large mammals in wild habitats, agencies such as the Arizona Game and Fish Department have built thousands of "wildlife waters," holding tanks or capture troughs that serve as communal watering holes in the middle of otherwise waterless protected areas. The Game and Fish Department also is the primary organization in charge of refilling and maintaining these water sources (Krausman, University of

Arizona, personal communication 2004), although hunter and conservation groups contribute time and funding on a volunteer basis. Despite uproar from some wilderness advocates, who say that using trucks to deliver water (very frequently during drought) violates the doctrine of "untrammeled" wilderness, many wildlife biologists advocate construction of even more wildlife waters.

The main argument in biologists' favor is that the artificial waters counteract the negative impact human actions have on wildlife in particular, and the desert environment in general. "[W]ater developments were viewed as a means to mitigate the loss of natural water sources resulting from diversion for agriculture, farming, ranching, domestic and industrial use, and human created barriers to wildlife movement" (Ballard et al. 1997). During drought, mobile species such as mule deer or endangered Sonoran pronghorn use more water to digest desiccated forage. With barriers such as freeways or fences blocking some water sources, the decline of total riparian areas, and the conversion of more rivers such as the Santa Cruz to only an ephemeral flow (Minckley and Brown 1994), normal wildlife adaptations to drought are impossible. Managers also construct water tanks throughout known animal ranges, since they expect higher densities of some species around the supplies. During drought, this allows for more distributed grazing, as well, so more animals might be able to use water for optimal grazing on dry forage (Burch and Grossi 1997).

The role of drought in our lives and our role in the incidence of drought

Negative impacts of habitat degradation have occurred through decades of normal precipitation *and* drought. It could be argued that human impacts in the Southwest, even without patterns of drought, would have caused the demise of riparian areas and negatively impacted populations of flora and fauna. Conversely, one could argue that even without human presence in the landscape, drought could cause streams to disappear, the water table to drop due to lack of recharge, and endangered species to perish. Both of these statements are, in fact, true. However, each is grossly insufficient to explain the role of drought in the lives of wildlife, humans, and the ecosystem.

When including drought—and the importance of such periods to the entire situation of human urbanization and wildlife habitat availability—it is vital to consider what we mean by drought itself. Redmond's definition of drought, "insufficient water supply to meet needs" (Redmond 2002), shows us that while precipitation will always vary, the degree to which supply is "insufficient" is relative to our demand. Thus, an ecological drought, one that is defined as "less water gained by an ecosystem in a period than is lost," could also be re-defined in human terms. During periods of "normal" precipitation, the ecosystem could, because of negative gains to the hydrologic cycle, experience a human-induced drought. This concept is vital to managing water supplies and monitoring withdrawals, since not only climate is dictating how much water is available in ecosystems anymore. Humans may not feel the effects of a climatological drought due to Central Arizona Project and Salt River Project supplies. The altered ecosystem, however, may feel drought effects even in the absence of a defined climatological drought. One might even say that certain plants and animals are always subsisting in a state of drought, albeit not a "natural" one, since even when precipitation levels are average, human water draw results in less-than-average amounts of water available in an ecosystem. This creates a new baseline of ecological health that bears careful consideration.

Another important aspect to defining drought is considering how it is measured. During a climatological drought, ecosystems experience increased stress. Vegetation during drought is

stunted, if it grows at all, and there are fewer nutrients available in plant leaves or cactus pads that many animals rely on in times of stress (Sowell 2001). While water tables normally decline during drier months, drought indices, such as those that the United States Drought Monitor uses, may not separate the compounded effects of this dryness and drought to increased evapotranspiration and reduced water table levels (Figure 4) (Davis 1993). During drought, the effective wildlife habitat quality continues to decline until the monsoon season, which during prolonged drought may not bring sufficient precipitation to raise aquifer levels.

Since humans need to guarantee their own ability to "turn on the tap," they draw more water from aquifers and surface supplies, especially in rural areas. This ADDITIONAL water demand from an already stressed water cycle has a much larger impact on plant and animal populations than it would during periods of normal precipitation. Human, animal, and plant communities are living closer to their "margins," as it were, during drought, and any decrease in water or food supplies, or reduced ability to adapt by moving to better habitat, can prove catastrophic.

In years when precipitation is merely at or below average levels, we may have to consider ecosystems to subsist in a permanent "human-induced drought." Although it is true that above-average precipitation might relieve the effects of a human induced drought, it is also true that the continued water demand from water systems in a state of climatological drought seems to be enough to overwhelm adaptive capabilities of many plant and wildlife species.

Drought impacts on wildlife: concluding points

In summary, and in light of compounded stresses on wildlife populations that are often overlooked, the following points could offer managers new areas on which to focus efforts to understand the role of drought in wildlife population health and movement, and the public education about wildlife and new perspectives on which to base their role in an ecosystem where habitat, water, and other resources are shared with wildlife species.

Discussion among wildlife biologists and managers has shifted, somewhat, from proving or disproving desert animal dependence on water to analyzing vegetation quality, water requirement thresholds, and habitat use. It appears that, for many species, vegetation quantity and quality dictate animal habitat use in years of normal precipitation more does than the availability of free water. Only during severe drought, when vegetation is desiccated, does water availability become increasingly important.

Drought, in addition to other climatic and habitat variations, is a major driver of wildlife population numbers and health, although its impact on vegetation may be most important. Indices to assess potential and progressive impacts of drought on Arizona's wildlife populations should take several things into consideration:

1) Individual species have different water requirements. Some species regularly survive without any intake of free-standing water, while others are riparian obligates. Most fall somewhere in between, using water seasonally during lactation, or in the dry spring when vegetation is desiccated.

2) A comprehensive assessment of habitat availability, accessibility, and quality is vital in determining wildlife ability to adapt to drought. The habitat condition can also reveal whether groundwater is available, whether the area has received adequate precipitation, and whether

animals lower on the food chain are likely to be healthy. In addition, winter precipitation and streamflow forecasts may be able to serve as forecasting tools for wildlife habitat quality. If little snow falls in the mountains, spring runoff may not be sufficient to fill ephemeral streams, let alone recharge the aquifer. Just as water managers use a streamflow forecast to predict the availability of urban water supplies, wildlife and range managers could use this to determine how resistant the ecosystem may be to spring and summer precipitation deficits. Where succulent and other desert vegetation health declines, so will the reproductive rates of many species, and eventually populations of wildlife will decline as well. In years of extreme drought, Sonoran pronghorn have been shown to concentrate their foraging efforts on habitats containing chain-fruit cholla, which offer surviving pronghorn more nutrients and a source of preformed water when other plants are desiccated or dead. Without access to those habitats, populations experience severe declines such as those seen over the past few years' drought (Bright and Hervert 2004, in press).

3) Drought impacts on wildlife may occur on several timescales. Species such as mice, squirrels, and packrats may feel impacts first since they are dependent on vegetation and seed availability in a relatively small area. Other herbivorous animals, such as deer, pronghorn, and elk may expand their range to find better forage. They may not experience negative impacts until drought affects extensive regions, limiting higher-elevation or low-elevation riparian areas that were reliable areas during less severe conditions.

Carnivore populations may feel a lag effect of impacts following a drought, rather than at the peak of climatologically-defined water deficits. Animals they depend on for prey, especially larger ungulates (which may themselves only feel impacts after many months or even years of drought and progressive degeneration of habitat) may not reach a critical stage of food scarcity until years into—or even after—a major drought. Like large herbivores, many carnivores respond to prey shortages in their home territories by expanding their ranges. Media reports attribute wandering black bears in Phoenix and wayward bobcats in Tucson to drought-induced food shortages in the wild.

Finally, scavengers may fare best during drought; raccoons, skunks, and other animals able to focus their diets to temporally and spatially available food supplies would seem to out-compete the other species that are limited in their resources. This increased adaptability may make them more dependent on urban resources, however.

4) Drought impacts on a species' population viability are best measured through effects on reproductive success. Precipitation and healthy forage conditions during certain months or even weeks can make the difference between population decline or growth. The crucial time for precipitation differs depending on the species in question. For example, a heavy spring rain may mean life for quail hatchlings dependent on a post-rain grasshopper hatch. Sonoran pronghorn fawns, on the other hand, thrive only when spring rains fall consistently and the summer monsoon arrives early, since they cannot subsist for long periods on nutrient-poor forage as adults sometimes can.

Just as the Southwest can experience a "wet year" nested within a dry period, so too can a specific species experience a "good breeding season," due to key timing of resources, within a longer period of overall population decline. Also, while one good year can dramatically increase population health through high recruitment of young, one poor year can dramatically decrease population health. As in the case of Sonoran pronghorn, this variability can lead to dramatic population increases or devastating losses (Bright and Hervert 2004, in press).

A new consideration of drought as an ecosystem process

Within Arizona's wildlife management agencies, there is no drought plan specifically addressing drought impacts on wildlife, or the appropriate responses to mitigate such impacts. Descriptions of immediate and specific status of species in certain parts of the state are part of hunter information databases, which also include descriptions of species' typical habitat choice in years of normal and reduced precipitation. Although not scientific, they are one of the only consistently available sources of population data available.

A comprehensive document describing impacts on population numbers of a wide range of species—not only urban, game, and endangered animals—would inform wildlife managers and the public about baseline population health. During periods of drought, impacts may build so gradually that the severity of drought effects on wildlife may not appear until sudden "crises" occur (see again Figure 1). At that point, conditions may be so severe that wildlife populations at all levels of the food chain die, or dramatically extend their territories into urban areas. Closer monitoring and ongoing habitat health assessments could allow managers and others to better understand the population dynamics of multiple species in Arizona's ecosystems, as well as prepare for inevitable contacts between wildlife and humans in voraciously expanding urban developments.

Arizona's wildlife management agencies could also expand on an idea of the State of Utah and develop their own animal drought response plan(s). The Utah Division of Wildlife Resources prepared a "Drought response plan for wildlife," which details impacts on wildlife, in particular on aquatic, terrestrial, upland game, waterfowl, and sensitive species (Utah Division of Wildlife Resources, online at http://www.wildlife.utah.gov/news/02-07/drought.html).

Ideally, a wildlife drought response plan for Arizona's animals would include ways to mitigate the actual mortality related to drought, a task which Utah's plan states is difficult to fulfill. Mitigation in the Utah "Drought response plan for wildlife" seems to be limited to relieving inevitable complaints from people concerning drought-related behavior in wildlife. For example, it states that during drought farmers can expect increased crop depredation, and the Division should be prepared to respond to more public complaints. Interestingly, the plan focuses less on the mitigation of drought stress on *wildlife* than on the actions the Division should take to mitigate drought stress on human recreational activities in managed lands. The plan does detail, however, specific losses that the Division can expect among some of its game populations, including deer, elk, fish, and more.

Additionally, the plan states that droughts "are natural [and] wildlife species are generally adapted to them, but drought is often unpleasant." While little can be done to mitigate the impacts of falling reservoir levels on fish populations (besides stocking "Conservation Pools" before a drought season occurs), the Division of Wildlife Resources focuses on continuing to promote fishing and hunting. "A reasonable harvest," the document says about fishing, "will minimize natural mortality next winter." Similarly, the document stresses that during drought, the Division should continue to make press releases that encourage people to visit protected lands to fish and hunt. "A harvestable surplus exists in hunted populations…even during drought years," the plan emphasizes, and hunting should "be used in critical situations where wildlife populations can potentially exceed a drought-reduced carrying capacity."

A more comprehensive drought plan for wildlife might also provide mitigation alternatives to reduce drought-related mortality, especially among non-game species whose

populations hunters do not control. It might also include a plan for informing the public not only about viable fishing and hunting options, but about ways for urban dwellers and wilderness recreators to respond to increased contact with many wildlife species—in the wild and in urban areas—that are searching for food.

Drought and wildlife, recommendations and actions

To improve the possible actions to future conflicts between wildlife and humans, in urban areas and beyond, managers, drought planners, and educators need a proactive plan. The following are recommendations to increase planning action, coordination between agencies, and public awareness. Currently, research on urban wildlife is scant, and may remain so, in part because little information or scientific data are available. Agencies—planning, management, public, and private—share the same challenges that regular reorganization poses for consistent record-keeping and ongoing, comprehensive monitoring of hundreds of species. While it may not be possible to implement a total inventory of species and the impacts that drought has on each one, any effort to improve awareness of regional changes in populations due to drought would contribute greatly to future management and research. In detail, recommendations to planners, managers, developers, educators, and the public:

- Develop a comprehensive "Drought response plan for wildlife," similar to the plan developed by the Utah Division of Wildlife Resources, to include impacts and mitigation for game, endangered, urban, and as many other species as possible

- Improve regular monitoring of species populations, ranges, and movement patterns to determine baseline ecological health; currently the range of "normal" behavior and movement for many species remains unknown and unstudied

- Record all urban wildlife complaints in a standardized database that the Game and Fish Department, Fish and Wildlife Service, National Park Service, Forest Service, BLM, and other agencies directly involved in the human/wildland interface could use

- Enhance public education programs to emphasize proactive, rather than reactive, measures to reducing human/wildlife conflicts in urban areas; these include the following points:
  - -Guidelines on daily living: no feeding of wildlife, keep pets indoors, plant native vegetation, and other measures *that are consistently enforced*
  - -Suggested behavior in the case of an aggressive animal encounter
  - -Strategies for maintaining educational/aesthetic contacts (e.g. wildlife viewing while hiking, bird watching in the backyard) without encouraging conflicts

- Include wildlife corridors in new developments, and reduce attractants and water use by restricting non-native vegetation, fountains and pools, and wildlife-feeding

- Recognize that humans and animals inevitably share limited habitat and resources, and while *contacts* will continue, people can act to reduce potential *conflicts*

In the future, increased understanding of the relation of drought to conflicts between humans and wildlife may be treated as not only a possibility but also as a *necessity*. Arizona will continue to experience drought and urbanization, and we can only benefit from preparing new ways to address ongoing conflicts in an educated and humane manner.

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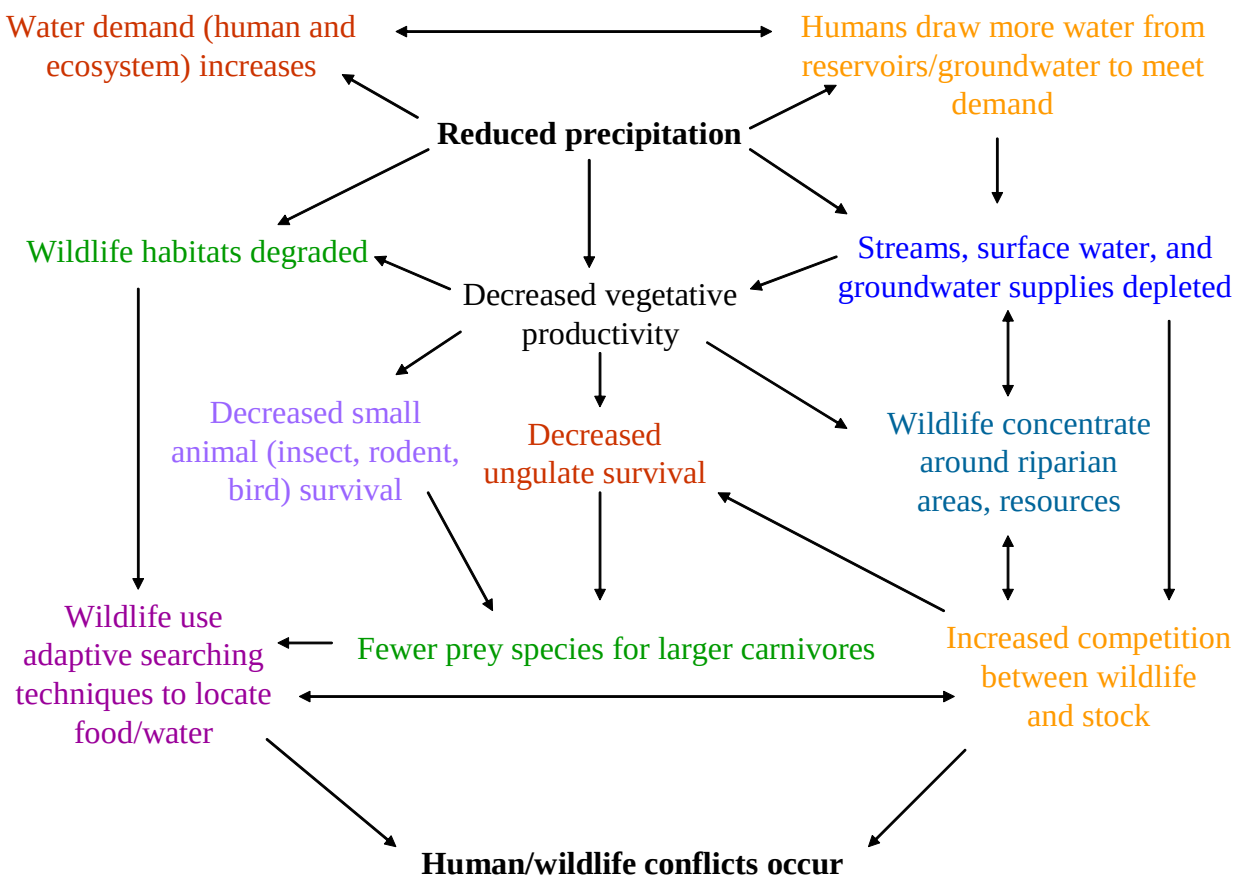

Figure 1. The impacts of reduced precipitation as they travel through an interdependent web of ecosystem users, and eventually result in human/wildlife conflicts. Reduced precipitation impacts humans and wildlife species in different ways and over differing time scales. Vegetation, habitats, small animals, and ungulates (as well as other animals dependent on vegetation) experience negative impacts of drought first. After a "lag time," during which prey species populations decline, carnivore populations also may decline. Increased stress on wildlife species may lead to increased conflicts with human populations.

Animal group	Equation	R-square	F-statistic	P
All species	conflict reports = 245.84 - 0.7(cool precip)	0.31	$F_{1, 10} = 3.98$	0.077
Amphibian and lizard	conflict reports = 21.96 - 0.019(cool precip) - 1.34(cool temp)	0.74	Cp $F_{1, 10} = 20.02$	0.0021
			Ct $F_{1, 10} = 8.57$	0.019
Coyote and fox	conflict reports = 3.40 - 0.018(cool precip)	0.62	F 1, 10 = 14.8	0.004
Mammal	conflict reports = 1046.47 - 0.73(cool precip) - 62.66(cool temp)	0.55	Cp $F_{1, 10} = 6.59$	0.033
			Ct $F_{1, 10} = 4.31$	0.077
Skunk	conflict reports = 342.89 - 0.21(cool precip) - 19.20(cool temp) - 0.14(warm precip)	0.93	Cp $F_{1, 10} = 51.19$	0.0002
			Wp $F_{1, 10} = 12.87$	0.0089
			Ct $F_{1, 10} = 53.55$	0.0002

Table 1. Statistical results showing significant decreases in reported conflicts for animal types due to cool season precipitation, cool season temperature, and in one instance, warm season precipitation. Skunk conflict reports were tied to all three climatic variables. In the F-statistic column, Cp = cool season precipitation, Ct = cool season temperature, and Wp = warm season precipitation.

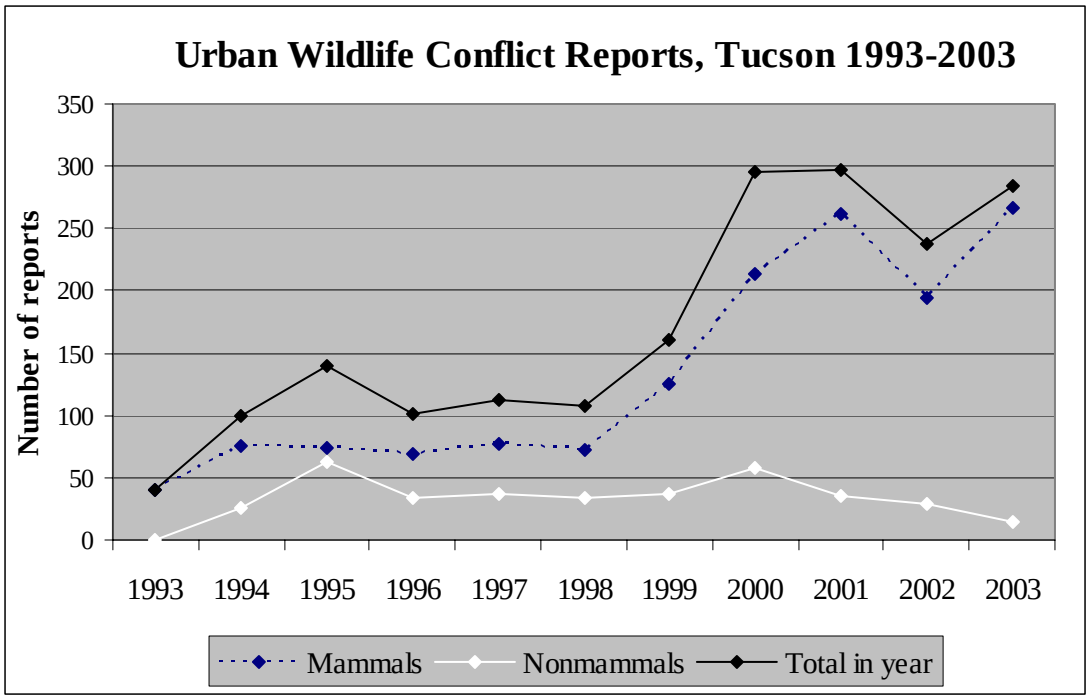

Figure 2. Total reported wildlife conflicts in Tucson, AZ, 1993-2003. Increased numbers after 1999 are mostly due to increases in small mammals, rather than the more visible large predators.

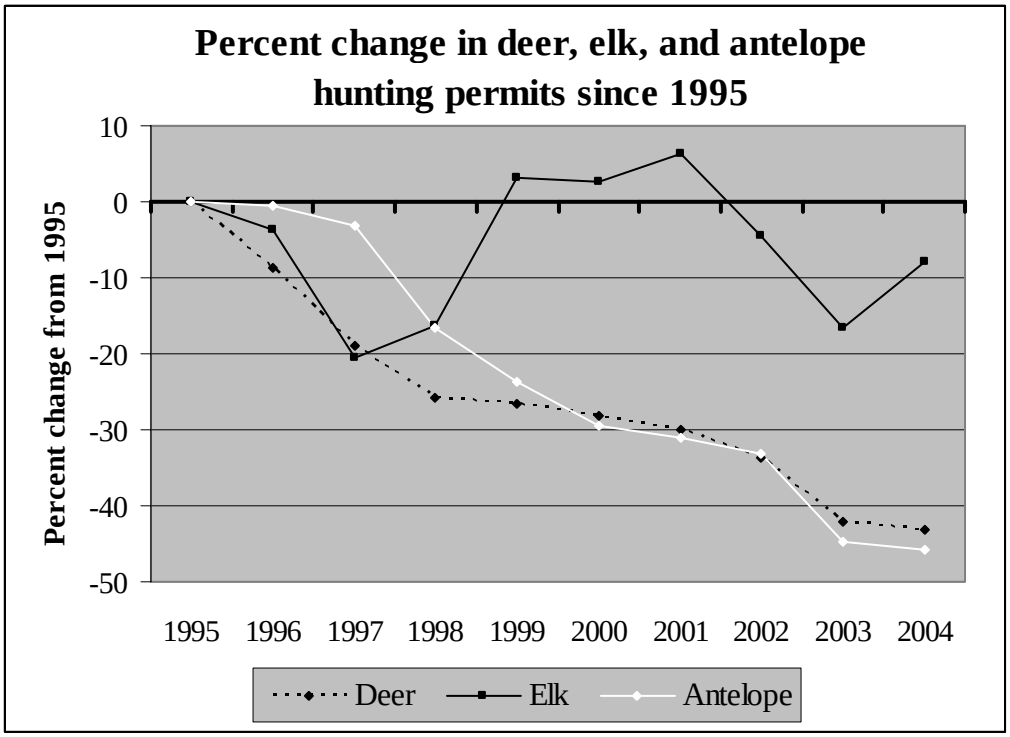

Figure 3. Total number of permits issued per year by animal type for each year's general hunting season. Permits for deer and antelope have been steadily declining since 1995. Reproduced from Hajek 2002.

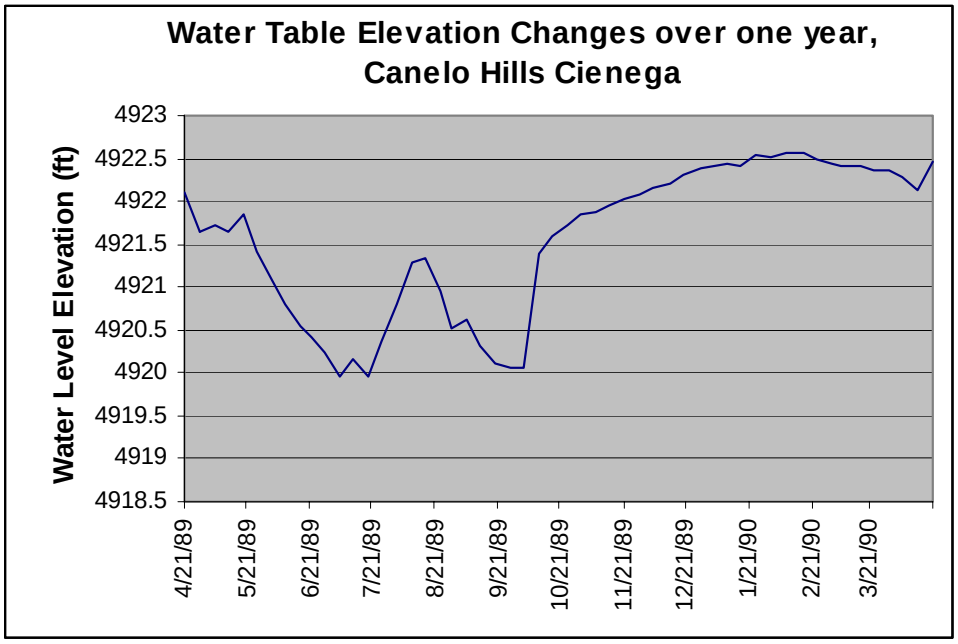

Figure 4. Seasonal water table reduction during a drought year, as seen in recorded water table levels from a monitoring study at Canelo Hills Cienega, Arizona. Note the decline in water levels throughout the spring (April to late July), as hot temperatures increase evapotranspiration, and no rain refills aquifer levels. Only until late summer monsoons does the aquifer refill. This represents fluctuations in a normal-precipitation year; during drought, aquifers may not refill to pre-spring levels, and may continue to decline over many years. Reproduced from Davis 1993.

Appendix IX
WORKGROUP REPORT – IRRIGATED AGRICULTURE

Governors Drought Task Force
Irrigated Agriculture Workgroup – Summary Report
09-28-04

Forward

This document summarizes the much longer and more detailed Irrigated Agriculture Work Group Report to the Governor's Drought Management Task Force. Discussion, findings, and recommendations are based primarily on a survey of irrigation district managers. Other supporting data include interviews with members of Arizona's irrigated agriculture community, reports and papers submitted to the Work Group, a series of public meetings, and anecdotal information. Data and discussion relating to the Sulphur Springs Valley has been extracted from a recent University of Arizona Report. From all this detail, only summary data is included in this version of the Work Group Report. Readers wishing to learn the basis for the discussion, findings, and recommendations presented here are referred to the longer and more detailed full Work Group Report.

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Discussion and Recommendations for Drought Planning: Preparedness and Response Options and How These Relate to Vulnerability and Impact in Arizona's Irrigated Agriculture 25

Abstract

Irrigated Agriculture has a storied and important history in Arizona. Its economic viability must be sustained over the long-term. A 2003 survey of irrigation district managers and a variety of other methods were used to investigate vulnerability, impact, and adaptation to long-term drought in Arizona's irrigated agriculture.

Irrigated agriculture in Arizona primarily uses surface water from the Colorado River mainstem and CAP canal, surface water from other principal Arizona streams, and groundwater. Irrigation district supplies are mostly influenced by how many of these water sources are available, water volumes available by source, related surface water priorities, and related physical and hydrological limits on groundwater withdrawals. Vulnerability to drought is also a function of these variables. Because the variables critically differ between irrigation districts, each district's vulnerability to drought also differs. Using these variables, the Report proposes five classes of irrigation districts.

From the survey, chief vulnerabilities to drought in 2003 included reliance on a single source of water, inadequate storage, widely varying precipitation, and low supply reliability. Trends expected by 2005/06 included severe supply shortages, increased reliance on single supply sources, lack of drought planning and preparedness, and uncertain and more costly power supplies. The current drought has generated a pronounced trend toward increased agricultural reliance on groundwater by many growers and several districts. Longer-term this trend may associate with declining water tables, increased production costs, deteriorating water quality, and other vulnerabilities.

From the survey, leading impacts expected if the current drought does not improve included increased groundwater depletion and water table declines, increased energy demand and reduced supplies, income loss for both farmers and irrigation districts, fewer planted acres, lowered financial viability of districts, and reservoir and lake drawdown.

Looking at drought adaptation and response, the Report suggests a strategic focus on longer-term preparedness and the more important and tractable vulnerabilities revealed by the Work Group, particularly supply. The survey listed 27 drought preparedness and response items and divided them into the five categories of: Voluntary, market-driven water transfers (79% of managers responded positively); programs (78% positive response); planning and research (58% positive response); forecasting and early warning (54% positive); and agricultural water conservation (35% positive). The more popular individual survey items included: Create a drought property-tax credit program for farmers (83% positive response); guaranteed low-interest loans to drought-stricken farmers (83% positive); short-term, voluntary, market-driven water transfers (79% positive); investment program to increase the flexibility of water supply sources (78%); develop a State water plan (75%); develop criteria to trigger drought-related actions (65%); and improve the accuracy of seasonal runoff and water supply forecasts (65%).

The Report addresses Eastern and South Eastern Arizona, and Dairies and Feed Yards, in separate sections in each chapter.

I. Introduction And Background

Economic Importance of Arizona's Irrigated Agriculture

Agriculture has a long and storied history in Arizona. Historians report that the Hohokam civilization disappeared from the Salt River Valley in the mid-1450's after having lived and farmed in the Valley for more than a millennium. Domestic livestock was introduced into Arizona by Spanish settlers in the early 1500's. Modern day farming activity in the Salt River Valley dates back to 1868 when Jack Swilling first diverted water from the Salt River to irrigate 1,000 acres of farmland. (Gammage, *Phoenix in Perspective, 1999).* The farming and ranching industries have been a primary factor in Arizona's economic wellbeing for over 500 years, producing food and fiber for the citizens of Arizona, the United States, and for export to overseas markets. Today, the value added to the State economy, including primary production and the forward and backward economic linkages to it, is estimated at $6 to 7 billion dollars annually.

Objective of this Plan

The objective of the Irrigated Agriculture Work Group, consistent with the Executive Order authorizing it, is to

> Assess the vulnerabilities, risks and impacts of drought on Arizona's irrigated agriculture sector and develop response, mitigation and adaptation strategies to sustain the long-term economic viability of the State's irrigated agriculture in the event of protracted drought.

Commercial cattle feeding and dairy production operations are included here because these confined operations are impacted by drought more similarly to irrigated agriculture than range livestock (see Chapter II Annex, "Dairies and Feed Yards").

Drought and Irrigated Agriculture

Drought impacts agricultural water supplies and water demand. The extent of the impact can vary significantly from one irrigation district, or farmer, to another based on many factors. Agricultural water users are impacted by meteorological, hydrological and socioeconomic drought. As precipitation declines (meteorological drought), systems reliant primarily on surface water supplies will be impacted more immediately than groundwater dependent systems that draw on water supplies stored over thousands of years. Systems with deep wells in productive alluvial aquifers will be less impacted than systems with wells in fractured rock or near streams that experience widely fluctuating groundwater levels in response to climate conditions. This impact on supply from long

periods of precipitation shortfall is referred to as hydrologic drought, which typically lags behind meteorological drought. In Arizona, hydrologic drought that occurred in past years or at great distances from irrigated agricultural areas can have profound impacts, because our surface water supplies often originate from surface storage or as precipitation over distant areas. Additionally, as groundwater levels or surface water supplies diminish, water quality can become a concern. In droughts, water demand typically increases as farmers apply more water to meet crop demand in response to increased temperatures which generally accompany drought. In cases where drought severely impacts agricultural water supplies, economic impacts may result at the irrigation district, at the farm, and in the community. These types of impacts are collectively called "socioeconomic drought".

Less water for delivery by irrigation districts impacts their revenue stream while increasing costs of system maintenance and the possibility of increased power costs as increased reliance on groundwater supplies is needed to replace surface water supplies where applicable. Farmers may face changes in cropping patterns and farm management methods that generally have negative impacts on farm income. Ultimately, severe drought conditions can lead to fallowing of irrigated land negatively impacting the financial well being of the farming operation. In acute situations there may be short term community impacts, less crop inputs purchased, and decreased use of farm labor. In chronic drought situations local communities with dependence upon production agriculture for their economic viability will be impacted.

Methods

The analysis, findings, and recommendations in the Irrigated Agriculture Work Group Report are based on a drought survey targeted at the irrigated agriculture community. The survey was developed in mid-2003 and distributed to 42 irrigation district managers statewide. By the end of 2003, twenty-two completed surveys had been received from irrigation districts located in Yuma, Yavapai, Maricopa, Pinal, and Pima counties, covering nearly every region of the state and accounting for an estimated 2,180,000 acre feet of water delivered to approximately 686,600 acres of farmland in each of the baseline years of 2000 and 2001.

The drought survey questions covered the general areas of:

- Irrigation District Water Supply Sources
- Drought Vulnerability
- Drought Impacts
- Drought Response, Mitigation and Adaptation

Additional sources of information included interviews with members of Arizona's irrigated agriculture community, reports and papers submitted to the Work Group, a series of public meetings, and numerous reports provided by irrigation water managers and producers at various 2004 forums addressing the impact of drought on Arizona's irrigated agriculture (see, for example, Chapter III Annex, "Impact of the Drought on the San Carlos Irrigation District").

The survey, and therefore the most important findings and recommendations, represent a snapshot in time, late 2003. The drought has worsened since then, and several Work Group representatives have stated that survey responses might differ today.

Eastern and South Eastern Arizona

For purposes of this report, areas in Eastern and South Eastern Arizona will be discussed under separate subheadings in each chapter. Geographically, this discussion covers the Upper Gila – Safford Valley area, as well as the Sulphur Springs Valley, that is, agricultural areas lying along a line roughly connecting Bonita, Wilcox, and Douglas. These areas are discussed separately because there is only one large irrigation district in the entire area, thus non-survey data sources are used more extensively than elsewhere in the Report. In the case of the Upper Gila –Safford Valley, our survey of district managers includes a single response – the 23rd – received in early 2004, from The Gila Valley Irrigation District

In the case of the Sulphur Springs Valley, where irrigated agriculture completely relies on groundwater delivered from privately owned wells, we rely on data collected by a team of researchers from the Bureau of Applied Research in Anthropology, at the University of Arizona[35]. An electronic version can be found at http://www.ispe.arizona.edu/climas/pubs.html.

[35]. Marcela Vásquez-León, Colin Thor West, Barbara Wolf, Jane Moody, and Timothy J. Finan. *Vulnerability to Climate Variability in the Farming Sector – A Case Study of Groundwater-Dependent Agriculture in Southeastern Arizona.* The Climate Assessment Project for the Southwest (CLIMAS). Institute for the Study of Planet Earth, The University of Arizona, Tucson. CLIMAS Report Series CL 1-02, December, 2002.

II. The Supply of Water to Arizona's Irrigated Agriculture

Sources of Supply

Irrigated agriculture in Arizona uses three primary sources of water. These are surface water from the Colorado River mainstem and CAP canal; surface water from other principal Arizona streams, of which the Gila, Salt-Verde, Agua Fria, and Santa Cruz River systems are the more important; and groundwater. State law also recognizes two other water sources, so called 'in-lieu' water and effluent. Physical in-lieu water derives from CAP and effluent. Effluent was a supply source in only two responding districts. Locally occurring precipitation is of relatively minor importance over most of Arizona's larger irrigation districts, but for districts relying on surface water, precipitation on often distant watersheds is the original water source.

Use of surface water depends on flow volumes – which vary annually – and is governed by priority of claim or permit, as detailed on page 15 of the Draft Operational Drought Plan of August 17, 2004. For those irrigating with surface water, vulnerability to drought in Arizona irrigated agriculture is importantly influenced by priority of use. In other words, the ability to irrigate with surface water would depend in large part on the volume of available water and on the priority rank of the user. Available volumes and priority rank are legal, institutional, physical, and hydrologic in nature.

Use of groundwater depends on location, specifically whether or not the use (point of diversion) is located within one of the State's five active management areas (AMA's). For those irrigating with groundwater at this writing, vulnerability to drought is related more to physical and hydrologic factors than to legal and institutional ones. There is discussion of groundwater management in Arizona on pages 13 – 15 of the 8/17/2004 Draft Operational Drought Plan.

So, the supply of water to those relying on irrigation district deliveries is mostly influenced by how many water sources are available to the district; water volumes available to the district by source; related surface water priorities; and related physical and hydrological limits on groundwater withdrawals.

Concerning individual growers, or groups of growers, who irrigate and are located inside of irrigation districts, some use only district supplies, some use both district supplies and their own individual wells, and some use only their own individual wells. When district supplies are curtailed, for example by drought, individual growers may replace district supplies by increasing their private groundwater withdrawals, to make a full complement of water.

An important amount of irrigated Arizona agriculture relies on groundwater withdrawn by individual growers, who may or may not also have access to irrigation district supplies. At this writing, in general, for those individual growers irrigating with

groundwater withdrawn from their own wells, vulnerability to drought is primarily related to the same physical and hydrological limits faced by wells owned, leased, or operated by irrigation districts. Groundwater for irrigated agricultural use by individual pumpers is an important water source in Eastern and South Eastern Arizona, to a lesser but still important degree in Central Arizona, and to a small degree in Yuma and along the Colorado Mainstem.

Classification of Irrigation Districts by Sources of Supply and Geographic Location as Reported by Irrigation District Managers

The survey asked for the approximate number of acre feet the district delivered[36] to irrigated agriculture in years 2000 and 2001 (this survey section is reproduced in an Annex to Chapter II in the full Work Group Report). It then asked about what percentage of district supplies came from each of six sources during those baseline years and during 2003. Finally, the survey asked managers to look out a dozen years, and indicate how they thought district supply sources might change. The water supplies of interest were those of the irrigation district, not those of individual growers or groups of growers within the district. This survey information is presented on Table 1.

The survey permits a classification of irrigation districts by the number of water sources available to the district, by their geographic location, and by their baseline volumes delivered. The six water sources are: CAP; other Colorado River water (mainstem Colorado); non-CAP surface water; district groundwater; in-lieu; and other. These last two categories consist entirely of effluent or CAP surface water delivered in-lieu of groundwater pumping.

Responding Districts that Rely Solely on Colorado River Mainstem Surface Water with Priority[37] 1, 2, or 3 Rights

Four Yuma County irrigation districts in this category responded to our survey: Unit "B", Wellton-Mohawk, Yuma ID, and Yuma County Water Users Association. Together, the four delivered just under 750,000 acre feet (af) of irrigation water in both baseline years (Table 1). These four districts all enjoy senior water rights to their mainstem Colorado River water (in the full Work Group Report, see the Chapter II Annex by Don Pope). The senior rights greatly limit the vulnerability of these districts to hydrologic drought. Other Yuma County districts also hold senior Colorado River rights, as do several mainstem Colorado River Indian Tribes.

Responding Districts that Rely Entirely or Almost Entirely on CAP and In-Lieu Supplies – No District-Delivered Groundwater

[36]. Both the survey and the Work Group are concerned with water deliveries, not with consumptive use or some other measure of water volumes.

[37] . For a discussion of priorities to Colorado River and other surface water supplies, see the Background Document in the full Task Force Report.

		TABLE 1: Statistical Information As Reported By Irrigation District Managers - Sources of Water in %																					
		'Normal' AF Delivered		Mainstem Colorado			CAP			In Lieu			Other Surface			District Groundw.			Other Sources			Total	
RRIGATION DISTRICT	CO.	2000	2001	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2015
Gila Valley ID	Gra	0	0																			0	0
McMullen Valley IDD	LaP	0	0																			0	0
Harquahala Valley IDD	Mar	100497	93867				100	100														100	100
Hyder Valley IDD	Mar	4	4													100	100	M				100	100
Maricopa Water District	Mar	60144	55257								40	L	60	40		40	20	M				100	100
New State IDD	Mar	907	527										71	50	L	29	50	L				100	100
Roosevelt ID	Mar	169063	166732													80	80		20	20		100	100
Salt River Project	Mar	152916	146278				14	10	L	19	22	L	45	29	M	22	39	L			M	100	100
San Tan ID	Mar	3525	2919													100	100					100	100
Tonopah ID	Mar	14514	15056				46	37	L	54	63	M										100	100
Paloma IDD	Mar	136936	138153											15	L		85	M				0	100
Roosevelt WCD	Mar	98043	98836							82	50	L			M	18	45	L	0	5	M	100	100
New Magma IDD	M-P	92995	90603				47	53	L	53	47	L										100	100
Cortaro-Marana ID	Pim	35000	32000				8	8	L				50	50		42	42					100	100
Central Arizona IDD	Pin	233167	221261				60	55	L							40	45	M				100	100
Hohokam IDD	Pin	75023	74027				30	54	M	70	46	L										100	100
Maricopa-Stanfield IDD	Pin	230333	242366				46	51	L	19	5	L				35	44	M				100	100
San Carlos IDD	Pin	39307	73378				7	12	M				60	18	M	33	70	L				100	100
Hilander "C" IDD	Yum	0	0																			0	0
Unit "B" IDD	Yum	28606.14	26617.15	100	100																	100	100
Wellton-Mohawk IDD	Yum	400000	400000	100	100																	100	100
Yuma ID	Yum	62102	60036	100	100																	100	100
Yuma County WUA	Yum	249432	238783	100	100																	100	100
Totals		**2182514.14**	**2176700.15**																			0	0

Volumes delivered are in acre-feet. L = Less, M = More. The survey referred to the years 2000 & 2001 as 'normal' rather than baseline.

Notes on 'Other Surface' and 'Other Sources' :

MWD: Surface water from the Agua Fria system.
New State: Supplies delivered by SRP.
SRP: Surface water from the Salt-Verde system.
Paloma ID: Gila River water diverted at Gillespie Dam into the Gila Bend Canal; mostly 91st Ave. plant plus Buckeye IDD drainage. Paloma did not deliver water in 2000/01
CMIDD: Water withdrawn from wells constitutes all CMIDD supplies, except for CAP water.
SCIDD: Surface Water from Gila system.
RID: Other would be the 23rd Ave plant.

Four irrigation districts in this category responded to our survey. Harquahala Valley IDD, Tonopah ID, New Magma IDD, and Hohokam IDD are all located in Maricopa and Pinal Counties. Together, these four delivered about 283,000 and 274,000 acre feet of irrigation water in the baseline years. These four districts (as opposed to their individual growers) are dependent solely on in-lieu[38] and CAP supplies (Table 1) with a junior priority[2]. In effect, these districts have no control over their water supplies, and are therefore among the most vulnerable districts to prolonged hydrologic drought on the Colorado River.

Most if not all individual growers (or groups of growers) in these districts have access to groundwater from privately owned wells. In some districts, total volumes delivered from privately-owned wells may exceed volumes delivered by the district. Under most circumstances, if individual growers experience reduced deliveries of CAP or in-lieu supplies, they will increase groundwater withdrawals, to deliver a full water supply.

Responding Districts that Rely on CAP Supplies (Including In-Lieu) and Also Deliver Groundwater

Central Arizona IDD, Maricopa-Stanfield IDD, and Roosevelt WCD responded to our survey. Together, they delivered about 562,000 acre feet of irrigation water in both baseline years. These districts can adjust the balance between surface and groundwater supplies. District groundwater is withdrawn from wells owned, operated, or leased by these districts (not individual growers or groups of growers). CAIDD and MSIDD balance groundwater and Junior CAP surface water, augmented (in the case of CAIDD) by some in-lieu water. RWCD combines in-lieu and groundwater. There are no grower-controlled wells in either CAIDD or MSIDD.

To deliver full supplies in 2003, these districts all increased groundwater withdrawals, as supplies to agriculture of CAP and in-lieu water decreased. Because of this ability to substitute groundwater for surface water, at least to some degree, these districts are somewhat less vulnerable than those districts relying solely on CAP and in-lieu supplies. However, reliance on increased groundwater withdrawals is associated with other vulnerabilities, discussed below.

Responding Districts that Rely on Non-CAP Surface Water and Also Deliver Groundwater

Five districts in this category responded to our survey. Maricopa WD, New State IDD, SRP, Cortaro-Marana ID, and San Carlos IDD are located in Maricopa, Pima, and Pinal Counties. Together they delivered about 288,300 and 307,440 acre feet of irrigation water in the baseline years. To varying degrees, these districts can balance surface and groundwater supplies. District groundwater is withdrawn from wells owned, operated, or leased by these districts (not individual growers or groups of growers). Most surface water comes from the Agua Fria, Verde, Salt, Santa Cruz, and Gila River systems augmented to a relatively minor degree by CAP (including in-lieu).

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[38] . In-lieu supplies derive from either CAP or effluent.

Because of a greater relative balance in their water sources, these districts are generally somewhat less vulnerable to long-term hydrologic drought than those relying exclusively on CAP supplies, but more vulnerable than the high priority mainstem Colorado River districts. Recent widely fluctuating surface water supplies have increased the vulnerability to long-term hydrologic drought in several of these districts.

Individual growers (or groups of growers) who experience reduced district deliveries may also have access to groundwater from privately owned wells and may increase private groundwater withdrawals. In 2003, this did occur, as a result of highly fluctuating surface water supplies in principal Arizona streams.

Responding Districts That Rely on Groundwater for at Least 80% of Supplies

Six responding districts rely on groundwater for 80 to 100% of their irrigation water supplies. McMullen Valley IDD, Hyder Valley Irrigation and Water Delivery District, Hilander 'C' IDD, Roosevelt ID, Paloma IDD, and San Tan ID are geographically dispersed throughout Maricopa, La Paz, and Yuma Counties. Together, these six delivered about 309,500 and 307,800 acre feet of irrigation water in the baseline years. Hilander 'C' and McMullen Valley IDD do not deliver water, rather growers there irrigate with water withdrawn from their own privately owned wells. Hyder Valley is very small, delivering just four acre feet of water in each of the baseline years of 2000 and 2001.

Approximately 80% of RID's water supply is withdrawn from district-owned wells. The remaining 20% is 'other' water, in this case effluent from the 23rd Avenue plant. Approximately 85% of Paloma IDD's water supply is withdrawn from district-owned wells. The remaining 15% is Gila River surface water diverted into the Gila Bend Canal at Gillespie Dam. The source of this surface water is effluent from the 91st Avenue plant and may include Buckeye WCDD drainage. The ability of these districts to substitute between water sources is limited by their high reliance on groundwater. The vulnerability of these districts, and the growers within them who also irrigate with privately-owned wells, will depend on physical and hydrologic factors, such as well yield, depth to water, and volumes available for withdrawal.

Eastern and South Eastern Arizona

The Gila Valley Irrigation District (GVID) encompasses about 35,500 acres, most of which are cropped annually. The GVID does not deliver water, but represents ten different canal companies within the District. The canal companies deliver water to farmers who also irrigate with privately owned wells. Some canal companies also own wells. Surface water rights in the Safford area are authorized through the Gila River Decree. Gila River surface water is allocated to the canal companies in accordance with the Decree. During most of the preceding five years, little or no Gila River surface water

has been allotted, therefore, virtually all recent irrigated agriculture in the Safford valley has relied on groundwater, whether withdrawn from individually-owned wells, or by the canal companies.

The Sulphur Springs Valley encompasses approximately 60,000 acres and includes agricultural areas south of the Safford Valley, including the Bonita area and Willcox to Douglas. The region has no permanent sources of surface water, thus the development of irrigated agriculture has completely relied on groundwater from the Willcox and Douglas basins. The Willcox basin occupies the northern three-fifths of the valley and covers approximately 1,911 square miles. It is the largest source of groundwater with an estimated 45.3 million acre feet of groundwater stored to 1,2000 feet (ADWR 1994b). Within this basin the average well depth is 450 feet, but depths may vary from 100 feet in relatively shallow aquifers up to 700 feet in such areas as Kansas Settlement (Clark and Dunn 1997). The Douglas basin occupies the southern two-fifths of the valley and contains approximately 750 square miles. It has an estimated 32 million acre feet of groundwater stored at 1,200 feet (ADWR 1994a). The principal source of groundwater recharge for the basins is winter precipitation, including snowmelt from the surrounding mountain ranges, which is transported to the valley by streams and washes (Mann et al. 1978).

Trends in Sources of Irrigation Water Supplies

The survey – and our other data sources – allow an assessment of two types of trends:

- Did supply sources change in 2003, as compared to the 2000-2001 baseline; and
- Do managers anticipate that supply sources are likely to change over the next dozen years?

Effect of Drought: Changing Supply Sources in 2003 – Increasing Agricultural Reliance on Groundwater

Among the eight responding districts relying on balance between surface and groundwater, our responding district managers reported a clear trend toward increased reliance on groundwater and decreased reliance on renewable surface water supplies in 2003. (Table 1 – SRP, RWCD, CAIDD, MSIDD, SCIDD, and New State). This trend was prompted by increasing demands on and reduced availability of surface water supplies, as a direct result of drought.

Anticipated Changes in Agricultural Water Sources towards 2015 – Increased Reliance on Groundwater

Looking at the '2015' columns on Table 1, responding district managers expect greatly reduced reliance on CAP and in-lieu supplies by that time. The responding managers

expect to pump more groundwater to replace those surface supplies. The only districts anticipating less reliance on groundwater by 2015 – SCIDD, RWCD, SRP, and New State – have already reduced surface water deliveries and increased groundwater withdrawals because of drought. By 2015, these districts may be expecting a return to baseline surface flows, which would allow them to pump less groundwater.

A Note on Groundwater Withdrawals and the Vulnerability of Irrigated Agriculture to Long-Term Drought

Wells are an important source of water to Arizona's irrigated agriculture and can provide some insulation against shortages caused by drought. At the same time, long-term drought may expose irrigators using groundwater to increased vulnerability from several sources. Water tables may decline. This may affect well yield, and will increase the cost of pumping as more electricity will be required to lift the same amount of water. Quality often worsens as deeper water is withdrawn. Drought has already affected the quantity of electricity generated and this threatens to reduce power supplies and increase power costs at the same time as more electricity is required. Some wells may have been idle or infrequently used for long periods of time. Experience shows that such wells may require often costly rehabilitation before they again become fully productive. Finally, in most districts, it is physically impossible to serve all district lands from every well.

III. The Vulnerability Of Arizona Irrigated Agriculture To Long-Term Drought

Summary of Results – District Manager Survey

The survey listed eighteen circumstances that might make the irrigation district vulnerable to drought, either in the current 2003 situation or if the drought were to deepen into 2005 or 2006. Table 2 summarizes the results.

Table 2. Summary of Survey Results – Vulnerability Circumstances

Absolute Rank *by total number indicating in 2003 and 2005/06*					Delta Rank *by number in 2005/06 minus number in 2003*		
	2003		2005/06				
Vulnerability Circumstance *(n = 22[1])*	How many mgrs. *(no.[2])*	How much water *(maf[3])*	How many mgrs. *(no.[2])*	How much water *(maf[3])*	Vulnerability Circumstance *(n = 22[1])*	Delta *(no.[2])*	How much water *(maf[3])*
Single water source	8	1026	12	1553	Severe supply shortage	7	759
Lack of/inadequate storage	7	777	8	915	Lack of preparedness	5	517
Wide precip. variation	7	440	8	783	Single water source	4	527
High growth affecting supply	6	541	6	582	Sudden change in supply	4	483
Low priority water rights	4	417	6	728	Low water supply reliability	3	304
Low water supply reliability	4	212	7	516	Imported water supply	3	
Sudden change in supply	3	264	7	747	Uncertain/low power supply	3	265
No political will to act	3		2		Low priority water rights	2	311
Uncertain/low power supply	2	85.3	5	350			
Severe supply shortage	1	56.3	8	815			
Lack of planning/preparedn's	1	27.6	6	545			

1. All 22 responding managers indicated one or more vulnerability circumstances.
2. The number of managers who indicated the circumstance.
3. Thousand acre feet delivered by the districts during the baseline period, (2001 + 2002)/2.

These results[39] are used to discuss three questions:

1. In 2003, which were the more important irrigation district drought vulnerabilities, in terms of both the absolute number of districts and the volumes of water delivered? How did this vary by geographic location, sources of water, and priorities over water use?

2. Which vulnerabilities might irrigation districts be most exposed to if the current drought continues into 2005 or 2006?

3. Are trends in the vulnerabilities of irrigation districts to drought evident between 2003 and 2005/06, assuming the current drought continues?

Irrigation District Vulnerability To Drought in 2003

Looking at drought during 2003, vulnerability to a ***single water source*** was the most frequently experienced drought vulnerability and cut across all counties, water sources, and surface water priorities responding. Referring to Table 1, it is noteworthy that 9 of the 22 responding districts relied on a single source for all of their irrigation water, and three more districts relied on one source for at least 80% of their supplies.

In 2003, a tie for second occurred among two characteristics: Lack of or inadequate ***water storage***, and ***widely varying precipitation***. The concern over ***storage*** was more concentrated among district managers relying on the Colorado River (including CAP users), perhaps reflecting current reservoir levels in Lakes Mead and Powell. Concern with ***widely varying precipitation*** seemed of greatest concern among districts who depend significantly on surface water supplies, including those using all of Arizona's principal streams. Locally occurring precipitation is of relatively minor importance over most of Arizona's more important irrigation districts, but for districts relying on surface water, precipitation on often distant watersheds is the original water source.

Vulnerability ***to high additional demand*** resulting from high growth was the fourth-most frequent vulnerability circumstance mentioned, and this vulnerability was more concentrated among districts located on the urban fringes of Yuma, the southeast and southwest Phoenix valley, and north Tucson.

Tied for the fifth-most frequent 2003 vulnerability were two more characteristics: ***low water supply reliability***, and ***low priority water/contractual rights***. The concern over ***low reliability*** was evident among districts that use widely fluctuating surface water supplies and junior non-Indian agricultural pool CAP users. In 2003, ***low priority rights*** were of concern in districts relying extensively on junior CAP rights.

[39]. The one survey from eastern and south eastern Arizona is not included here, but is discussed separately at the end of this chapter.

Irrigation District Vulnerability if the Present Drought Continues Into 2005 or 2006

Vulnerability concerns by 2005/06 were similar to 2003, but district managers did signal several new concerns and, in general, expected exposure to a greater number of vulnerabilities if the drought continues.

Vulnerability to a ***single source*** of supply continued of greatest concern across all geographic locations, sources of water, and surface water priorities. When combined with the statistical information related to trends anticipated in 2015 (Table 1), we can see that the prospect of a prolonged drought is causing district managers to anticipate a decreased reliance on surface water and an increased reliance on groundwater.

The prospects of a ***severe supply shortage***, lack of or inadequate ***water storage***, and ***widely varying precipitation*** tied as the second highest concerns if the present drought were to continue into 2005/06. Concern that a ***severe supply shortage*** might develop by 2005/06 was spread across geographic areas, water sources, and surface water right priorities, but was not among the leading vulnerability characteristics mentioned by district managers in 2003. Concern about ***storage*** was more concentrated among responding senior and junior Colorado River users. Districts concerned about ***widely varying precipitation*** included those using all of Arizona's principal streams: the Colorado (whether senior or junior right holders), Agua Fria, Salt-Verde, Gila, and Santa Cruz Rivers.

Anticipated Trends between 2003 and 2005 or 2006, if the Drought Continues

The increase in concern over a potential ***severe shortage*** – from one to eight district managers – was the largest increase in concern with any drought vulnerability characteristic and was spread across geographic areas, water sources, and surface water right priorities. About two in five district managers may anticipate their water supply situations to seriously worsen if the current drought were to continue for even two or three more years.

The increase in concern over a lack of ***drought planning and preparedness*** that may develop over the 2003 to 2005/06 period – from one to six district managers – was the second-largest increase in concern with any drought vulnerability characteristic. This concern was spread across geographic areas; districts relying on groundwater, the Colorado and other surface water sources; both junior and senior right-holders; and volumes delivered. One interpretation of this information might be that more than one in four of our responding district managers attach importance to advance early warning: They would like to see a developing problem coming as far in advance as possible. Because a number of districts already have – and indeed, are implementing – contingency plans for dealing with district-level supply shortages, a second interpretation might be support for Statewide drought planning.

Concerns over dependence on ***single supply*** sources tied for the third-largest vulnerability trend. To the degree that this trend may also be associated with a decreased reliance on surface water and an increased reliance on groundwater, the set of specific vulnerability circumstances may change but overall vulnerability may further increase.

Vulnerability to ***sudden changes in supply*** was the other third place trend. CAP users experienced intensifying competition for water in 2003, and may be anticipating more of the same if the drought continues. This would lead to increasing vulnerability, the more so if the availability of other surface sources continues to diminish.

By 2005/06, ***Power supplies*** may become less certain and power supplies may fall. At the same time, power demand and unit power costs both may rise. These eventualities are likely to increase the total expenditure on power, whether at district or individual grower level.

Eastern and South Eastern Arizona

According to the manager of the Gila Valley Irrigation District, water supplies to irrigated agriculture in the Safford area are vulnerable to low reliability, sudden changes, periodic severe shortages, and contamination, and all of these factors are in turn related to natural disasters such as flooding and widely varying precipitation. Other vulnerability circumstances in the Upper Gila Valley area include a lack of drought forecasting, planning, preparedness, and data and low priority water/contractual rights. The District Manager noted only one trend if the drought continues, increasing reliance on groundwater as the single water source. A number of irrigation wells in the Valley are relatively shallow. The service areas for shallow wells are expected to become more reliant on surface diversions as groundwater levels decline with continuing drought. However, surface diversions have been mostly unavailable during recent years.

Since the 1970s, groundwater overdraft has been a major concern throughout the Sulphur Springs Valley region as more groundwater is being pumped than recharged. With long-term drought, water levels decline and the price of energy increases, the cost of groundwater irrigation goes up, and with it the vulnerability of irrigated agriculture. Given the present drought, access to water presents perhaps the greatest challenge to the local farming industry, and those whose crops require more water tend to be more vulnerable. As drought lowers the water table, knowing if the dry winters will continue is the most important factor in deciding whether to continue farming.

Vulnerability to drought, however, is not only related to hydrologic and climatic conditions. Farmers rely on both vertical (institutional) and horizontal (social capital) networks to reduce their vulnerability. These formal and informal networks provide access to climate information and to financial and other assets that allow farmers to respond to drought and adapt. Farmers under disadvantaged socioeconomic conditions have a more difficult time recovering from and adapting to drought.

Discussion and Recommendations for Drought Planning: Water Supply and Drought Vulnerability Options

If correlated with geography to a degree, water supply to Arizona's irrigated agriculture is more a function of the number of water sources available at a specific location, the volumes available from each source, priority rights and claims, and physical and hydrologic limits on groundwater withdrawals including access to groundwater, its quality, volumes available, and the ability to deliver it locally. Geographic distance or time often separate the origin of irrigation water from its place of use. The vulnerability of irrigated agriculture water supplies during drought is directly related to these variables, and drought preparedness involving irrigated agriculture must recognize diversity across irrigation districts with respect to them.

Keeping these caveats in mind, one approach to drought management and longer-term drought planning and preparedness is to focus on the more important and tractable supply vulnerabilities revealed by the Irrigated Agriculture Work Group.

Vulnerability resulting from the number of water sources available at a particular location and the physical and hydrological limits on groundwater withdrawals can be amenable to strategic intervention. For example, wheeling, increasing inter-connectivity, or facilitating willing and voluntary market-based trades where applicable are options for diversifying water sources. Likewise, facilitating well rehabilitation and improving the ability of wells to command larger areas are options to help relax physical and hydrologic constraints on groundwater withdrawals, again where applicable.

Looking at specific circumstances, the Working Group was concerned first and foremost with reliance on single sources of supply, both now and over the next two or three years. The options mentioned in the previous paragraph – wheeling, increasing connectivity, or voluntary market-based trades – might address single supply concerns, as well as such other vulnerabilities as low supply reliability or sudden and severe shortages.

A lack of or inadequate storage was also a chief concern, and the Working Group notes that large impoundment projects are not the only way to address this problem. Small local regulatory storages and recharge projects are being used effectively at several Arizona locations. Irrigation districts use sumps, ditches, or ponds to capture and reuse tail water.

Concern over uncertain or low-priority power supplies has intensified during 2004. Any measures that will help rural power districts tie down long-term power supplies are likely to be increasingly important to Arizona's irrigated agriculture.

Arizona's vulnerability to a statewide lack of drought planning and preparedness will be alleviated considerably when the Operational Drought Plan is finalized. Monitoring, data and triggers, local area impact assessment groups, and interagency coordination address Work Group concerns. Increased emphasis on longer-range, location specific weather forecasting would address agricultural vulnerabilities in irrigated areas that rely heavily on shallow, precip-recharged aquifers, such as Eastern and South Eastern Arizona.

IV. Impacts

Summary of Results – District Manager Survey

The statewide survey of irrigation district managers listed seventeen drought impact statements (Chapter IV Survey Section Annex, full Work Group Report), and asked the following question:

> "Below are several statements regarding the possible impacts across the *DISTRICT* of the current drought. Please circle the number that best describes your opinion about how the current drought might impact conditions in the *DISTRICT*, assuming water supply does not improve over the next year or two. Considering the statement, is the drought likely to cause:
> 1 = Minor or no impact;
> 2 = Some impact;
> 3 = Significant impact."

Table 3: Summary of Results – Long-Term Drought Impacts
Top and Bottom Five Statements, Ranked by Total Score[40]

Top Five Statements *(by total score)*	Total Score	No. '3's	Bottom Five Statements *(by total score)*	Total Score	No. '1's
Increased GW depletion/w. table decline	47	11	Air quality effects/PM-10 problems	24	15
Increased energy demand/reduced supply	41	7	Insect, disease, pest infestation	27	13
Income loss – farmers and the District	41	7	Decreased land prices in the District	27	14
Fewer planted acres in the District	38	6	Cost of water transportation	29	11
Financial viability of the District	37	5	Water quality effects	32	10
Reservoir and lake drawdown	37	7			

All twenty-two managers[41] responded to at least one of seventeen statements. The Work Group divided the 17 impact statements into four categories:

- ✓ Supply depletion and other environmental concerns
- ✓ Other impacts – energy demand and supply
- ✓ Financial viability, income loss, and land prices
- ✓ Agronomic impacts: Planted acres, crop quality, land productivity, pest infestation, and yield declines

Water Supply Depletion

[40] . The scoring system is explained in the full Work Group Report.
[41] . Again, the 23rd survey, from GVID, is discussed separately, on page 19.

If water supplies in responding districts do not improve over the next year or two, the responding managers expect impact from groundwater depletion, water table declines, and reservoir and lake drawdown (full Work Group Report, Chapter III Summary Table). Impacts from groundwater depletion and water table declines are expected throughout Maricopa, Pinal, and Pima Counties. Supply sources in concerned districts include groundwater, surface water from principal Arizona streams, and CAP. Several districts concerned about depletion rely on more than one source of supply. Looking at reservoir and lake drawdown, seven districts expected significant impact and those districts represented all surveyed areas, all priority classes, and all water sources. Again, districts that rely on several water sources were concerned about reservoir and lake drawdown.

Energy Demand and Supply

By the summer of 2004, drought had already impacted energy demand and supply in several responding districts. If water supplies do not improve over the next year or two, the responding managers expect these impacts to intensify, with several central Arizona districts indicating "significant impact". Increasing demand for and reduced supplies of power can combine to raise unit power costs and increase total power expenditures, whether at district or individual grower level. The pronounced move to groundwater has increased energy demand and raised power expenditures among well-operators, both individual and district. Power is supplied to many irrigators under fixed-price, long-term contracts. As these expire and are renegotiated in the current environment, those prices will rise. Power shortages feed-back to constrain water supply, while increased power expenditures exacerbate negative effects on income and financial viability.

Income Loss and Financial Viability

If water supplies in responding districts do not improve over the next year or two, the responding managers expect income losses to both farmers and the district and adverse impacts on the financial viability of irrigation districts. Secondary economic impacts – ripple effects – in the form of economic loss to secondary business and commerce dependant on primary agricultural production were also concerns several managers. To the degree that reduced water supplies translate into idled cropland, yield or quality declines, increased pest problems, increased costs, and the like, on-farm income is likely to be lost. These same effects can impact the financial viability of irrigation districts, because delivery volumes translate into a principal revenue stream of many districts – i.e., per acre-foot water charges. When delivered supplies fall, district revenues also fall. This has led some districts to increase per acre assessments, which translates back to decreased on-farm income. Employment at districts, on-farms, and in other agriculturally dependant commerce can be negatively impacted in these circumstances.

Planted Acres

If water supplies in responding districts do not improve over the next year or two, the surveyed managers expect impact from fewer planted acres, in other words, drought will

cause the number of acres in production to decline. Anecdotal information provided by three managers indicates that, in fact in 2003, drought idled thousands of acres in those three districts, an impact that can be expected to worsen and spread if the drought persists into 2004 and 2005 (See SCIDD Annex to Chapter III in the full Work Group Report). This land idling was caused by drought-induced reduced stream flow, combined with junior claims that could not be compensated from other sources, such as wells.

Drought Impacts on Arizona's Dairies and Feed Yards

An extended drought could impact how and where Arizona's dairies and feed yards find and produce their water supplies (See the "Dairies and Feed Yards" Annex to Chapter II in the full Work Group Report). Any interruption of production – whether on animals being fed or to the production of grain and forage that supply the livestock feeding industry – due to declining or intermittent water supplies will be associated with severe economic impacts to Arizona's dairies and feed yards. A decline in feed quality caused by water shortage will have similar negative economic impacts. Any drought-induced lengthening of the feed supply chain (reliance on more distant feed) also implies increased cost to the industry.

Eastern and South Eastern Arizona

Sources in the Upper Gila – Safford Valley area report that declining groundwater tables have caused shallower wells to surge and well yields to decline, while surface water allocations from the Gila River have been at or near zero for several years. Planted acres have been cut back. The GVID survey notes significant negative impacts in all of the survey summary categories. Water supplies are depleting. Energy demand is increasing while supplies are declining or being curtailed. There has been income loss for farmers and the ditch companies, as well as economic loss to secondary business and commerce directly dependent on primary agricultural production.

Overdraft and declining water tables have been a chief concern in the Sulphur Springs Valley (SSV) since before the 1970's. Under conditions of long-term drought, access to water becomes the principal limiting factor for agriculture in the region. Access is largely determined by the depth from which water has to be pumped and the costs of pumping it. Meanwhile, the SSV is subject to the same drought impacts on power demand and supply experienced elsewhere in Arizona and the southwest. So, drought in the SSV tends to increase the depth to water and pumping costs. These associate with increased water supply uncertainty and increased costs to farm. During the 1970's, declining water tables caused a large percentage of farms in the SSV to go out of business.

Discussion and Recommendations for Planning: Drought Impacts and How They Relate To Vulnerabilities

While it may be appropriate to target short-term drought response at drought impacts, longer-term drought preparedness might more effectively target vulnerabilities. In general, it appears that managers from those districts relying on a combination of groundwater from either district or individual grower wells plus Junior CAP supplies (including in-lieu) were **more likely to indicate 'significant impacts'** on the survey.

Several of trends discerned in Chapter II are about to translate into, and in some areas have already translated into, **income loss for farmers and districts** and adverse impacts on the **financial viability of districts**. Fewer planted acres is one source of income loss and decreased financial viability. From Chapter III, related vulnerabilities of note include severe supply shortages, sudden supply changes, low water supply reliability, and uncertain or low priority power supplies. Longer-term, focus on these vulnerabilities will probably better prepare irrigated agriculture for drought. Related preparedness options were recommended on page 18.

Reported **supply depletion** impacts appear to reinforce Chapter III discussion about a seriously worsening supply situation if the drought continues to deepen for even two or three more years. The impacts associated with reservoir and lake drawdown translate into an increased reliance on and use of groundwater, which associate in-turn with increased groundwater depletion and water table declines. In terms of Chapter III vulnerabilities, **supply depletion** impacts can be associated with lack of and inadequate storage, wide precipitation variation on watersheds, and low water supply reliability. Looking at trends, it seems clear that drought and other recent supply effects are impacting groundwater supplies in Arizona. **Supply depletion** may translate into higher production costs and fewer planted acres. Reader attention is again drawn to the page 18 discussion of preparedness options related to low reliability, shortages, and storage.

Impacts from **increased power demand and reduced supply** also appear related to vulnerability trends noted in Chapter III. One trend is the increasing drought-induced reliance on groundwater, which may cause static water tables to fall and lifts to increase. The second trend is drought-induced exposure to uncertain or low priority power supplies. A net effect was noted, that power demand and unit costs both may rise at the same time as power supply may be diminishing. This increases total power expenditures, whether at district or individual grower level, in-turn increasing district and grower financial vulnerability.

In 2003, **fewer planted acres** in three affected districts were associated with vulnerabilities related to uncertain or unreliable supplies, wide precipitation variation on watersheds, dependence on single sources, and inadequate storage.

V. Response, Adaptation, and Preparedness

Summary of Results – District Manager Survey

The statewide survey of irrigation district managers listed twenty-seven drought preparedness and response items (Annex to Chapter V, full Work Group Report). The Work Group distinguished between drought preparedness and response. *Preparedness* is action taken in advance of an impending drought. It is proactive and adaptive, designed to lessen the vulnerability to and the impact of future drought. By contrast, *Response* refers more to dealing with an existing or imminent drought situation. It is reactive, aimed at mitigating drought effects about to be or already being experienced.

Looking at the 27 items individually, the following, in order, had the highest percentage of ***positive*** district manager responses[42]:

Preparedness and Response Item	Positive (%)
Create drought property tax credit program for farmers	83
Guaranteed low-interest loans to drought-stricken farmers	83
Short-term, voluntary, market-driven water transfers	79
Investment program: Increase flexibility of water supply sources	78
Develop a State water plan	75
Develop criteria to trigger drought-related actions	65
Improve accuracy of seasonal runoff and water supply forecasts	65

Looking at the 27 items individually, the following, in order, had the highest percentage of ***negative*** district manager responses[43]:

Preparedness and Response Item	Negative (%)
Five physical conservation practices[a]	76
Four management conservation practices[a]	69
Establish new data collection networks	65
Study effectiveness of water conservation measures	65

a. Most respondents said these were already available.

The Work Group divided the 27 items into these five categories:

- ✓ Forecasting and early warning
- ✓ Programs

[42] . A *positive* response was an affirmative answer that the item either "might help some," or was "potentially very important."
[43] . A *negative* response was an affirmative answer that the item was either "already available," or, "would not help."

- ✓ Agricultural water conservation
- ✓ Voluntary, market-driven water transfers
- ✓ Planning and research

On a category basis, the breakdown between positive responses – either "might help some", or "potentially very important" – and negative responses – either "already available" or "would not help" – was:

Item Categories	Positive (%)	Negative (%)
Voluntary, market-driven water transfers	79	21
Programs *(4 items)*	78	22
Planning and Research *(4 items)*	58	42
Forecasting and early warning *(5 items)*	54	46
Agricultural water conservation *(13 items)*	35	65

Eastern and South Eastern Arizona

GVID sources indicated that all 27 drought preparedness and response items from the survey either might help some or were potentially very important. The GVID district manager indicated that the more important items included developing drought triggers, early warning systems (long-range forecasts), and a statewide water plan. Drought property tax credits and guaranteed low-interest loans for drought-stricken farmers were also potentially very important. Promising conservation measures included canal lining, underground pipelines, and irrigation scheduling by crop water demand.

In the Upper Gila Valley – Safford area, because of the institutional organization of water rights, there may be little incentive to conserve water, in that any water saved by one simply becomes available for use by another, without compensation. Also, there was a need to reconcile agricultural with environmental issues: Measures such as canal lining might conflict with environmental rules and regulations.

As an agricultural region dependant on groundwater for irrigation, the Sulphur Springs Valley (SSV) provides insights into both the vulnerability of Arizona's irrigated agriculture and the adaptation strategies that may contribute to the long-term economic viability of irrigated agriculture in a semiarid environment where access to water is decreasing. Large-scale commercial agriculture became possible in the Sulphur Spring Valley with the establishment of the Sulphur Springs Valley Electrical Cooperative in the 1940s. Inexpensive energy to power electric pumps for irrigation, plus increased demand for cotton during World War II, led to a farming boom, attracting farmers to the SSV to produce mainly cotton and corn. Agricultural acreage expanded rapidly until 1976 when irrigated acreage reached a peak of 160,000 acres. But, annual water withdrawal began to exceed recharge in the late 1960s and static water depths began to drop. Droughts between 1973 and 1980 exacerbated the problem to the point that, in 1980, part of the region was declared as an Irrigation Non-Expansion Area and no new Irrigation Acres

were allowed. The energy crisis of 1976 led to an exorbitant increase in the price of natural gas. In combination, these climatic and economic events drove farming families out of the region and, in the course of a few years, irrigated acreage declined by more than 66 percent, the largest decline of any agricultural region in Arizona.

Adaptation in the Sulpher Springs Valley

In the Sulphur Springs Valley, farmers expect and have adapted to a great deal of climatic variability from one year or season to the next and are concerned about climate variation that might affect the water table. Because farmers perceive that winter precipitation is the main source of aquifer recharge, they want winter precipitation forecasts that extend two to five years into the future. This knowledge would have direct relevance on decisions to deepen wells, to continue improving the efficiency of irrigation technology, to change cropping strategies, or perhaps to leave farming.

The repeated water supply crises in the SSV have prompted adaptations that include changes in irrigation technology and crop diversification in response to market signals. An important adaptation to low and erratic precipitation has been the adoption of more water efficient irrigation technologies. By the beginning of the 1990s, most larger farmers had replaced older flood furrow irrigation systems with newer center pivots, sprinklers, and drip irrigation.

Crop diversification has also been an important adaptation. Some abandoned fields were changed to fruit, pecan, and pistachio orchards. Other parcels were converted to food-grade corn, chile, lettuce, and a wide variety of other vegetables. Those who continue to grow traditional row crops such as corn, sorghum, cotton, and alfalfa generally do it in combination with other crops. High water costs have caused other farmers to target niche markets such as those for organic fruits and vegetables.

Public policy has played an important role in facilitating these changes. Since the 1940s, farmers have benefited substantially from a variety of federal commodity programs. More recently, the Environmental Quality Improvement Program – EQIP – and other Federal and State programs have provided farmer incentives to adopt water efficient irrigation technologies. Crop insurance, including prevented planting insurance, is becoming increasingly important in allowing farmers to recuperate from extreme events.

All of these adaptation strategies have allowed SSV growers to become better prepared to deal with future extreme climatic and economic conditions, but their adoption has not been uniform. Smaller farmers – those cultivating smaller plots of land – have been less capable of adopting new technologies or diversifying crop production and are more vulnerable to climatic extremes.

Discussion and Recommendations for Drought Planning: Preparedness and Response Options and How They Relate To Vulnerability and Impact in Arizona's Irrigated Agriculture

The information about preparedness and response can be interpreted in light of the analyses of drought vulnerabilities and impacts presented in previous chapters. The idea of voluntary, willing, term-limited, and **market-driven water transfers** received positive responses of "might help some", or "potentially very important", from fifteen of nineteen (79%) responding district managers. Voluntary and market-driven water transfers offer one means of preparing for or responding to several of Arizona's chief drought vulnerabilities, such as reliance on single supplies, inadequate storage, a threat of severe shortages, or sudden supply changes. Voluntary and market-driven water transfers further offer an approach to relieving such drought impacts as supply depletion, drawdown, and income loss to both farmers and irrigation districts. Experience elsewhere in the West shows that all parties to a successful transfer can and must benefit. Great care will be required if this avenue is explored as a drought preparedness or response item. But, over a longer-time, a term-limited and voluntary market approach may offer great promise to Arizona as a drought preparedness tool.

Programs received positive responses from 78% of the district managers. All individual program items included on the survey were popular with the responding district managers. Programs can be used to respond to an existing drought or to prepare for a long-term drought eventuality. Looking at specific program items, property tax credits and low-interest loans received the highest percentage of positive responses, followed by any type of investment program that would increase the flexibility of water supply sources. Any such programs could address the shortage, storage, or supply vulnerabilities reported in Chapter III.

Specifically, these types of **programs** could be used to improve on-farm or district distribution systems, or to increase well command areas. They could be used to promote system inter-connectivity or to add small regulatory storages. They could link to the conservation ideas discussed below, in fact, analogous types of programs are presently in use in some Federal and State incentive conservation programs. Such programs can further act to lessen the income and financial impacts reported in Chapter IV.

Looking at the items dealing with both **planning and research** and **forecasting and early warning**, the mildly positive response to these items can be evaluated in the context of those vulnerability circumstances of greatest concern to district managers: Single sources, widely varying precipitation, low water supply reliability, sudden water supply changes, the threat of severe shortages, and especially a current lack of drought planning and preparedness. One interpretation is that district managers would like to see any supply problems developing as far in advance as possible, which may reflect the trend noted, namely that supply problems already existed in 2003 and have become worse in 2004. In the forecasting and early warning category, developing criteria to trigger drought-related actions and improving the accuracy of seasonal runoff and water supply forecasts received the most positive responses from the district managers. These items are addressed in the draft Statewide Operational Drought Plan.

Our statewide survey of irrigation district managers listed thirteen **agricultural water conservation** drought preparedness and response items. Overall, 65% of the responding managers said the list of thirteen items were either already available or would not help. An even higher negative response was observed to the nine physical or management conservation items listed on the survey. The Irrigated Agriculture Work Group suggests that these results should be interpreted against the backdrop of the enormous statewide conservation investments that have already been made by Arizona's irrigated agriculture at both district and on-farm levels. Conservation incentive programs have been in place over many years in most of Arizona's irrigation districts. Many district managers may see limited conservation potential in management-type approaches, perhaps reflecting a view that the performance of most growers is already high in this area. The Work Group suggests that the most promising approaches to continued agricultural water conservation might include:

- ✓ Continued participation, on a voluntary basis, in existing incentive programs directed at physical and structural conservation improvements, targeting growers who may still benefit from voluntary participation in such programs;
- ✓ Continued participation, also on a voluntary basis, in private or publicly supported agronomic and water management outreach programs, again directed at growers who volunteer to participate;
- ✓ Continued use of tax credits, low-interest loans, crop insurance, and like programs targeted at drought preparedness, along the lines of several existing programs already popular with Arizona growers.

Water conservation in Arizona's irrigated agriculture is discussed in detail in Chapter IV of the Full Work Group Report.

A Caveat About the Increasing Reliance on Groundwater

The present reversion to groundwater as a primary irrigated agriculture supply source cannot be an effective or even workable drought management strategy over a longer-term, for the same reasons that led to the 1980 Groundwater Code. Water tables will decline, affecting well yield and increasing the cost of pumping. Quality is likely to worsen as deeper water is withdrawn. Drought has already affected electricity generation and this threatens to reduce power supplies and increase power costs at the same time as electricity demand increases.

Institutional Context Restraining Drought Adaptation and Response

Eligibility requirements for popular Federal and State programs currently place restraints on certain types of drought response, for example land idling. Eligibility for the Environmental Quality Improvement Program (EQIP) requires the land placed under contract to have been farmed during at least two of the prior five years. Each time Federal commodity programs are renewed, 'base acre' provisions are usually attached. These constrain eligible program acreage to have been planted to specific commodities during a certain number of immediately preceding years. Financially, owner-operators cannot generally simply opt-out of farming when faced with difficulties such as drought. The

same may be true of lessees with high fixed costs, such as machinery and equipment amortization requirements.

Appendix X
WORKGROUP REPORT – MUNICIPAL & INDUSTRIAL

Arizona Drought Preparedness Plan
Impact and Drought Assessment
Municipal &Industrial Work Group Report
DRAFT 9/29/04

1. M&I Drought Issues and Historic Impacts

Drought impacts municipal and industrial water supplies and water demand. The extent of the impact can vary significantly from one water provider to another based on many factors. Municipal and industrial water users are impacted by meteorological, hydrological and socioeconomic drought. As precipitation declines (meteorological drought), systems reliant primarily on surface water supplies may be impacted more immediately than groundwater dependent systems that draw on water supplies stored underground over thousands of years. However, groundwater supplies may not be sustainable over the long-term, 50-100 years, if groundwater uses outstrip natural or artificial recharge. Systems with deep wells in productive alluvial aquifers may be less impacted than systems with wells in fractured rock or shallow wells near streams that experience widely fluctuating groundwater levels in response to climate conditions. This impact on supply from long periods of precipitation shortfall is referred to as hydrologic drought, which typically lags behind meteorological drought. Additionally, as groundwater levels or surface water supplies diminish, water quality can become a concern. In droughts, water demand typically increases as water provider customers apply more water to outdoor uses such as landscaping. In cases where drought severely impacts domestic water supplies, public health issues may arise such as the potential for backflow, should a storage tank go dry, or insufficient water for sanitary needs. As water supplies become limited, economic impacts may result, such as unemployment in certain sectors or significant reductions in revenue or income. These types of impacts are collectively called "socioeconomic drought".

Recent and past droughts have impacted municipal and industrial water users in a number of specific ways. Information on these impacts has been reported from several sources. These include the 2003 Arizona Short-term Potable Plan, a 2003 rural water resources questionnaire sent to almost 600 water providers, tribal representatives and jurisdictions outside of the State's active management areas, newspaper articles, and a recent drought survey distributed as part of the long-term drought planning effort. The drought survey and a facilitated M&I Workgroup meeting conducted in October 2003 were the primary sources used in identifying drought impacts and vulnerability in this sector. Prior to the meeting, a four-page drought survey was emailed to almost 800 people on the GDTF list. The drought survey questions covered the general areas of:

- Drought Vulnerability,
- Historic Drought Impacts,
- Drought Monitoring and Forecasting,
- Drought Planning, and
- Drought Response.

After the October Work Group meeting, the four-page survey was also mailed to an additional 18 domestic water providers identified as having experienced drought related challenges or located in areas of the state with the potential to be impacted. See Attachment 1 for more discussion on this drought survey.

Approximately 60% of the respondents to the 2003 Rural Water Resources Study questionnaire reported that drought had affected their water supply. Declining groundwater levels and increased peak demand were commonly noted as problems. Not all water providers identify drought as one

of their priority issues; smaller rural systems in particular are faced with a number of serious infrastructure and supply problems that overshadow or cannot be distinguished from the effects of drought.

The Arizona Short-Term Potable Plan, released in July 2003, and updated in July 2004 noted that the ongoing drought reduced water supplies to several providers causing an emergency situation. In response, some relied on trucked water. Other providers were identified as at risk. Based on information from the Department of Emergency Management, the Department of Environmental Quality, and the Arizona Corporation Commission (ACC) and from the 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.

When providers were asked to comment on how historic droughts had impacted their systems, several noted that they had to shift to using more groundwater as their surface water supplies dwindled. Phoenix area water providers were impacted by reduced surface water supplies from the Salt River Project (SRP). The City of Flagstaff is investigating drilling new wells in response to severely reduced surface water supplies. Others noted well failures in surrounding rural areas that resulted in a need for the nearby water provider to supply hauled water. Small capacity domestic wells were also impacted by drought as water levels declined, particularly those with shallow wells and those pumping from fractured aquifer systems. In addition, small providers often lacked sufficient storage or a back-up supply.

SRP has responded to the ongoing drought by reducing water allotments to its water rights holders and providing replacement supplies. The replacement supplies include additional groundwater pumped from within the SRP service area and Central Arizona Project (CAP) water. This has resulted in increased expenditures for water supplies. SRP's groundwater pumping expenditures have increased from an average of $1.5 million per year from 1992 through 1996 to an average of $4.7 million per year from 1997 through 2003. In addition, from 1996 through 2003 SRP purchased more than 400,000 acre-feet of water from the CAP at a cost of more than $11 million and borrowed an additional 125,000 acre-feet that must be paid back. SRP also received almost 450,000 acre-feet of CAP water from 1996 through 2003 in lieu of pumping groundwater at a cost of more than $6.5 million (part of SRP's groundwater savings facility project). The "in-lieu" CAP water is stored underground as recharge credits and will be pumped in the future to mitigate the impacts of drought.

In an attempt to limit future impacts of drought, many water utilities in the Phoenix metropolitan area, and several in rural Arizona have adopted or are in the process of adopting drought plans to respond to the prospect of limited water supplies. The ACC is now requiring private water companies to complete curtailment plans when they come to the ACC for a rate case. While these curtailment plans are not specific to drought, they are intended to provide a plan to address any kind of supply shortage, drought induced or otherwise.

This chapter discusses municipal and industrial drought vulnerability, monitoring and forecasting issues and needs, drought mitigation strategies, and the roles and the potential responsibilities of local, state and federal entities in monitoring and responding to drought.

2. Statewide M&I Drought Vulnerability

Municipal and industrial water users exhibit a range of vulnerability to drought depending on their source of supply, hydrogeology of the source area, system storage, type of water system, type of water customers, legal access to water supplies and other factors. This section discusses the components of Arizona domestic water provider drought vulnerability.

a. Water System Organizational Structure Vulnerability

The way in which water systems can respond to drought is determined in part by their legal or organizational structure, which may limit operational choices. The corresponding differences in drought response may increase or decrease a water provider's vulnerability to drought impacts. In general, there are three types of domestic water systems in Arizona. They are:

- Public Water Systems

These are typically a municipal water system or domestic water improvement district, but can also be a county, state, or federal government facility. They have the authority for drought planning as well as implementing drought related curtailment actions, as their governance allows. These public systems can implement ordinances that restrict certain water uses or mandate water use restrictions.

- Private Water Systems

There are more than 400 individual water systems operated by nearly 350 companies under the jurisdiction of the Arizona Corporation Commission. Currently, 50 of them have completed Curtailment Tariffs, which can be used to address drought related problems. As companies come before the ACC for rate increases, they will also be required to have a Curtailment Tariff on file with the ACC. Many of these systems are very small and have limited financial resources.

- Small Domestic Wells

Domestic wells with a pumping capacity of 35 gpm or less typically serve only one residence but may also serve well co-ops and organized homeowner associations. These wells are called exempt wells, because they are exempt from ADWR regulations within AMAs although the term is commonly used statewide. However, the wells are subject to ADEQ and county health regulations if they serve more than 15 connections or 25 individuals. These small systems have very limited resources to make their systems less vulnerable to drought since they are typically organized as not for profit well share agreements. Restrictions on water use could be in the well share agreement, deed restrictions or in covenants, conditions and restrictions associated with a subdivision but enforceability would be difficult.

b. Water Supply Vulnerability

Types of water supply vulnerability include those related to physical water supply (including inadequate water supply planning), infrastructure, water quality, legal access to supplies, and economic issues. Depending on the location and water resources available to specific water providers, the following types of drought vulnerabilities may be present:

- Physical Water Supply
  - Inadequate physical water supply due to hydrologic limitations on the ability to access water. These can include reduced surface water flows, reduced spring flow, and falling groundwater pumping levels and reduced pump production with existing motor/pump configuration.
  - Systems with a single water supply source are more vulnerable than those with multiple supplies of water from both a quantity and quality perspective. Systems that utilize a combination of groundwater, surface water and effluent are generally better prepared for drought.
  - Providers with access to surface water from either the Salt River Project or Central Arizona Project are significantly buffered from the impact of drought by the significant

storage reservoirs on those systems. In both cases, the reservoirs are designed to hold a multi-year supply of water. The SRP also has the capability of supplying groundwater from its network of 250 wells to supplement surface water shortfalls.

- Inadequate water supply drought planning to account for extended periods of below normal water supply conditions leaves systems ill-prepared to respond to drought.

- Legal Access to Supplies
  - Vulnerability is also affected by the priority of surface water rights and Central Arizona Project contracts. The oldest surface water rights have the highest priority. CAP contractors with an M&I allocation have a higher priority than those having a non-Indian agricultural allocation. In general, Indian allocations are of higher priority in a CAP shortage condition until the M&I supply falls to 510,000 acre-feet. At that point, the 510,000 acre-feet shares priority with the remaining Indian priority water.
  - When water is pumped by a well close to a stream, surface water law and groundwater law come into conflict. In these areas the concept of a "subflow zone" was developed by the Courts. Subflow is water found in an aquifer that is more closely associated with a stream than a regional groundwater system. Wells within the subflow zone are presumed by the Court to be pumping surface water and not groundwater. Drought impacts on subflow may result in a legal access issue.
- Infrastructure
  - Insufficient water supply back-up systems increase system vulnerability. These can include standby wells, springs and surface water supplies, arrangements to temporarily purchase or borrow water from neighboring domestic systems, etc.
  - The physical stressing of equipment (wells, pumps, pipelines, etc.) during a drought can lead to infrastructure problems, especially in aging systems.
  - Inadequate short-term (meaning daily or weekly) water storage capacity within a municipal system can make a domestic provider vulnerable to drought. This is especially apparent in domestic systems that run low on water during the day but have excess pumping capability available at night. Additional storage may help in this situation.
  - Vulnerability is increased if there is inadequate monitoring of the water supply system, including monitoring of water storage levels, groundwater pumping levels and well discharge flow rates that would otherwise provide warning of supply limitations.
- Water Quality
  - Vulnerability to drought can be exacerbated by changes in water quality due to high temperatures and reduced surface water flows. In addition, increased groundwater pumping may change the distribution of contaminants in the aquifer.
  - Poorer quality groundwater may move to higher quality groundwater areas when wells are deepened to provide additional supplies during drought.
  - Water conservation (reduced flow) in response to drought can effect disinfection by-product concentrations and chlorine residuals in distribution system piping and storage reservoirs.
  - Introduction of new sources of water in response to drought may cause flow reversal in some parts of the distribution system, causing stable sediments to become mobile. This may result in undesirable chemical reactions within the system. See further discussion on Water Quality in Section ___.

- Economic Issues
  - Systems with an organizational size and/or structure that make it difficult to obtain sufficient funds for infrastructure maintenance and improvements are more vulnerable to drought (2003 CLIMAS Urban Water Provider Report, Carter and Morehouse). Smaller water systems also have a more difficult time realizing cost savings from economies of scale. Funding

for infrastructure projects from the Arizona Water Infrastructure Finance Authority (WIFA) is contingent on meeting fiscal capacity criteria. Local fiscal capacity, as defined by WIFA includes the following components: median household income, user fees (other charges for within the service area), and existing indebtedness in their calculations of ability to pay (R18-15-305, Ranking Criteria for the Drinking Water Revolving Fund Priority List). Meeting these criteria may be difficult for smaller systems.

c. Water Demand Vulnerability

To further compound domestic water provider challenges, water demands during droughts conditions often increase, even if lack of precipitation may not actually impact water supply availability Examples of increased water demands include:

- Increased landscaping water use to compensate for reduced precipitation and higher evapotranspiration rates from higher temperatures and lower humidity. This is more of an issue for the water provider when the percentage of outdoor watering is high compared to the total use. Jurisdictions often experience increased landscaping water use at public facilities, including parks, schools, golf courses and recreational ball fields.
- High temperatures commonly associated with drought increase the demand for cooling, resulting in increased water use. In addition, industrial cooling tower water use can increase due to higher concentration of certain constituents, such as total dissolved solids, that may damage the system. This condition reduces the number of cycles the water can be used before constituent concentration limits are reached, requiring increases in waste stream discharge or blow-down. This situation requires an increase in make-up water.

d. Vulnerability Issues identified in the 2003 Rural Water Resources Survey

As a part of the ADWR's 2003 Rural Water Resource Study, customized survey questionnaires were sent to nearly 600 water providers, jurisdictions, counties and tribes outside the AMAs. Surveys were sent to 496 water providers, 54 municipalities, 23 tribes, and 15 counties. Survey responses were received from 114 municipal water providers, 22 municipalities, 3 tribal entities and 10 counties. Twenty-three additional responses were received from miscellaneous types of systems and are not included in the results described here. While the response rate is considered good, responses are still limited and do not represent all areas of the state equally. The responses are summarized below:

Municipal Water Provider Responses:
This group included 86 private and 28 public and quasi-public water providers. Nearly 40% of the providers had been affected by the drought, but only 15% had a drought plan. Of the 46 systems that had been affected by drought, 43 reported an increase in potable demand and 11 reported a reduced supply of potable water.

In response to what type of assistance the providers would find useful in preparing for future droughts, 40% indicated a need for increased storage capacity. Demand management related assistance was a common response including the ability to charge higher fees for higher volume users, a drought-triggered conservation program and the ability to restrict deliveries to customers during drought

Jurisdictional Responses:
These included 22 responses from rural area cities and towns. When asked if they had been impacted by the drought in 2002, 45% replied in the affirmative. Twenty-seven percent of the respondents reported an increase in potable water demand, reductions in available potable water supplies and lowered groundwater levels.

When asked what type of assistance they would find useful in preparing for future droughts, half responded that drought-triggered conservation programs would be helpful. Other types of assistance most often mentioned was the ability to charge higher fees for higher volume deliveries customers during droughts, advance warning of drought conditions and the ability to distribute current climate information to customers.

County and Tribal Responses:
These included responses from ten counties, two tribes and one tribal district. When asked if they had been affected by the current drought, 60% of the counties and all tribal respondents replied in the affirmative. Five counties and all tribal respondents had experienced an inadequate water supply for grazing and wildlife And 3 counties and one tribe experienced an inadequate potable water supply. Inadequate water supplies for fire suppression were reported by 2 counties and 1 tribe.

County suggestions for drought planning assistance included assistance preparing drought and water conservation plans, coordination of planning efforts, and help regulating lot splits. County water supply suggestions included access to more drought resistant water supplies, increased water storage and determination of the water supply availability of groundwater basins. Information and education suggestions included drought status presentations, hydrologic updates, and a pre-packaged public water conservation education program.

Tribal suggestions for drought planning assistance included assisting in developing and implementing a range management plan, better planning, better water storage and better conservation, alternate water source development and providing or improving water hauling capabilities

Further discussion on the 2003 Rural Water Resource Survey Provider Survey results is found in Attachment 1.

e. Vulnerability Issues identified in the M&I Work Group Meeting and Drought Survey

Drought vulnerability responses from the M&I Drought Survey confirmed that access to multiple sources of water limits vulnerability although there may be increased cost associated with the substituted supply. Multiple supply utilization requires interconnected supply systems and in some cases, flexibility to create water exchanges. Increased vulnerability for small systems due to lack of alternative supplies and limited financial resources was mentioned and one respondent noted that they had provided hauled water to a neighboring small system whose wells had gone dry. In some cases, surface water that had been an important supply component were unavailable or limited and several respondents mentioned they were looking at drilling new wells or other capital improvements to limit vulnerability and were aggressively protecting their surface water rights. Groundwater level declines were noted. Systems in shallow aquifer areas had been affected resulting in difficulty in maintaining sufficient storage. One respondent observed that the ability to recharge water for future use was particularly vulnerable due to limited surface water available for recharge during drought and the low priority established for CAP water delivered for recharge purposes as opposed to direct use. The need to develop a long-term strategy to acquire sustainable water supplies was mentioned.

Other vulnerability issues noted were well depth, system leaks, and the ability to meet peak demands and the demands associated with tourism. Some noted that vulnerability is strongly related to economics and that regulatory issues (such as environmental regulations) may impact access to supplies. Others noted that landscapes were vulnerable due to reduced precipitation and

that drought-related reduction in demand due to voluntary or mandatory restrictions translated into potential lost revenue for the water company at a time when money for infrastructure is needed. However, of those responding to the survey, none mentioned having significant problems meeting customer's water demands.

Respondents noted that in the case of a long-term drought there could be a severe impact on the aquifer's ability to recover to pre-drought levels, increasing the potential for subsidence, further water level declines and poor water quality. They mentioned that an extended drought could result in difficulty meeting all demands and that additional expenditure on building storage capacity would be necessary. Survey results are found in Attachment 2.

f. Other Vulnerability Related Issues

Other issues related to municipal provider vulnerability to drought include:

- AMA v. Non-AMA

Within the State's active management areas (AMAs), the Assured Water Supply Rules require demonstration of a 100-year water supply for new subdivisions and for the service areas of water providers designated as having an assured water supply. These rules include meeting the standard of continuous availability during drought. However, outside of the AMAs, where the demonstration of an assured water supply is not required, there is no drought contingency supply required and drought related problems might exacerbate an inadequate water supply situation.

- Endangered Species Act (ESA)

The presence of endangered or threatened species increases the likelihood that habitat protection activities may affect the availability of water supply for other uses. Habitat for endangered species has been created by drought and the associated lowering of water levels in reservoirs, creating the need for habitat mitigation activities in the event that reservoir levels rise.

- Service Area Growth

Timely response by domestic water providers to service area growth based water demands is important. As a general rule, population growth almost always results in increased water demands. If existing water supply infrastructure cannot meet these new demands (or have yet to be installed and operational), shortages can occur. Growth related water supply shortages are not necessarily exclusively caused by drought, but are certainly exacerbated under drought conditions.

- Land Subsidence

In those areas of the state with deep alluvial fill material, the potential for land subsidence could result from increased groundwater pumping. Land subsidence can affect flow rates in gravity flow infrastructure such as sanitary sewers, storm drains, and irrigation canals. Once compacted, the storage capacity of the aquifer is permanently reduced, making the supply even more vulnerable in the future.

g. Statewide M&I Vulnerability Ranking

Since the vulnerability of water systems to drought is clearly related to the source of the water supply, this section of the M&I chapter proposes a general ranking system to identify the potential for temporary or permanent reductions in water supply based on the hydrogeological conditions found in the state.

In general, the vulnerability to drought can be ranked in terms of the timing and magnitude of impacts related to drought. If an entire water supply is derived from precipitation events, lack of rain will cause an immediate effect. On the other hand, if a water supply is derived from large regional aquifers with little recharge, and with large amounts of water in storage, you may never directly see the impacts of drought, at least in the short term (several years to several decades). The ranking system encompasses a range of relative vulnerabilities based primarily on the source

of supply, legal access to water, amount of water in storage and the potential magnitude and timing of the drought impacts. The ranking system begins with the most vulnerable water resource supplies.

1) Surface Water
Surface water supplies derived directly from precipitation and associated runoff are judged the part of Arizona's water supply most vulnerable to drought. Conventional practice in developing long-term surface water supplies typically includes storage reservoirs to provide water supplies during prolonged periods of lower than normal flows. Aside from the SRP system and the CAP and other Colorado River diversions, there are relatively few instances in Arizona where water supplies are derived solely and directly from surface water sources supplied by precipitation. Surface water sources are defined as small reservoirs, natural lakes, and direct diversions from seeps, springs, creeks and rivers. Artificial impoundments such as stock tanks, which depend directly on runoff, also fall into this category. Examples include the cities of Williams and Flagstaff, which are at least partially supplied by surface water systems that are directly and significantly impacted by precipitation quantity and timing.

2) Shallow Aquifers in and near Surface Water Courses
Shallow aquifers directly replenished by, and/or in hydraulic connection with, surface water flows are less vulnerable than surface flows because the aquifers are quickly recharged by the stream flow. Water is typically withdrawn through the use of wells. The groundwater storage capacity, depending on its size, provides a time factor, which slightly reduces the vulnerability factor when compared directly to surface water sources. Storage within these subflow aquifers is, however, generally quite limited. These aquifers are also relatively easy to define from a drought-planning standpoint. Examples include Black Canyon City, Tonto Basin and developments and cities located along the Upper Verde River.

3) Shallow, Small Aquifers Directly Dependent on Precipitation
Several regions of Arizona contain shallow aquifers that are highly dependent on precipitation for relatively rapid recharge and sustainability. These aquifers are different from the shallow aquifers categorized above associated with creeks and rivers (subflow). These aquifers occur in a variety of hydrogeologic environments from volcanic cinders to fractured bedrock. These shallow small aquifers are typically located in the Central Highlands or on the Colorado Plateau at elevations, which provide more precipitation than Basin and Range environments. The shallow aquifers are characterized by generally limited areal extent, relatively shallow nature (a few tens of feet to water), and moderate storage capabilities. Storage in an individual aquifer system is a function of the areal extent and thickness of water bearing material. Examples include shallow volcanic aquifers in the vicinity of Flagstaff and south of Show Low and the bedrock aquifer near Payson.

4) Aquifers of Intermediate Size Directly Dependent on Precipitation
Aquifers of intermediate size, which are directly dependent on precipitation for recharge, predominate in the Transition zone physiographic province (ADWR Central Highlands) and in some parts of the Basin and Range physiographic province. The Central Highlands basins generally receive more recharge due to higher rates of precipitation associated with the generally higher elevations of the Central Highlands. The aquifers are generally characterized by enclosed basins of moderate size with relatively shallow depths to water, at least prior to development. The intermediate aquifer basins are generally larger in areal extent and thicker than the shallow small aquifers described in Number 3 above and therefore have more storage capacity which tends to mitigate the temporal aspects of drought. Examples include the Little and Big Chino groundwater basins in the Central Highlands and the San Rafael and Cienega Creek basins in the

Basin and Range province. These intermediate aquifers are sensitive to reduced recharge in the longer term, but have more groundwater in storage, therefore they are generally considered to be the fourth most vulnerable source of supply subject to drought impacts.

5) Conjunctive use of Surface Water and Large Groundwater Basins

Large groundwater basins with augmentation from surface water supplies are a typical category of water supply scenarios in central Arizona. Direct recharge to groundwater from precipitation is small relative to the large amounts of groundwater in storage. The surface water components of these area's water supplies are used to augment or offset groundwater supplies, particularly in times of excess surface water availability. The surface water supply systems also have significant storage capacity in the form of dams and reservoirs. In the Salt River Project area, existing water rights systems limit the distribution of Salt River water to selected lands. These areas generally also have access to large amounts of groundwater in storage, which renders them less susceptible to drought. In addition, significant amounts of highly treated effluent have been recharged in central Arizona basins, which further reduces drought vulnerability. This category is similar in level of vulnerability to category 6. The only difference is partial reliance on a more vulnerable surface water supply that would require short-term adjustments in system management and operations.

Examples of conjunctive use systems include all of the major agricultural users and cities in the Salt River Project area who are dependent on runoff from the Salt and Verde River watersheds and Central Arizona Project users in Maricopa, Pinal and Pima Counties. While surface water supplies are directly impacted by decreased precipitation and the associated decline in runoff, investment in reservoir storage and underground storage through recharge can decrease vulnerability to drought impacts due to decreased precipitation. Surface water users, including SRP and CAP users are vulnerable to decreased surface water supplies in the case of long-term sustained drought. However, the timing of the impact may be delayed by reservoir storage and conjunctive use of groundwater.

Due to the large amounts of groundwater in storage relative to demands, the lack of significant recharge from precipitation, and due to storage in the surface water supply portion of the system, the conjunctive use surface water/groundwater systems are considered the fifth most vulnerable water supply susceptible to drought conditions. However, the longer the drought, the more susceptible these systems become.

6) Large Regional Aquifers

Large regional aquifers with large amounts of groundwater in storage (compared to demands and the recharge from precipitation) predominate in the Basin and Range physiographic province and in the northeastern part of Arizona. The amounts of water in storage are significant and, where not seriously overdrafted, provide a reliable source of water in spite of reduced precipitation associated with drought. The effects of reduced precipitation, in all but the most specific cases, would likely go unnoticed for years if not decades. As a practical matter, the large regional aquifers are not susceptible to short-term droughts as a function of the large amounts of water in storage. Minor impacts, such as increased pumpage to make up soil water deficits in irrigated areas, usually accommodated by precipitation, would be felt, but overall little impact would be seen. The large regional aquifer systems are judged least susceptible to the impacts of even a prolonged drought. Examples of areas overlying large regional aquifers include the Tucson metropolitan area prior to the importation of CAP water and the burgeoning development in and around the Casa Grande area. As is the case in conjunctive use basins, significant volumes of highly treated effluent have been recharged in these large regional aquifers, reducing drought vulnerability.

3.Drought Monitoring and Forecasting

a. Current Monitoring and Forecasting Activities

There are many sources of information on climate and drought conditions, including forecasts available to municipal and industrial water users. Sources include the U.S Drought Monitor, National Drought Mitigation Center, National Climatic Data Center, NOAA Climate Prediction Center, CLIMAS (Climate Assessment for the Southwest), National Weather Service Arizona Drought Data Website and others. In the SRP and CAP service areas, users rely on SRP and CAP water reports and on Bureau of Reclamation forecasts for the Colorado River. Monitoring is conducted by many agencies (USGS, NOAA, NWS) discussed in detail in the monitoring sections of the Drought Preparedness Plan. Some water companies also conduct regular monitoring activities such as groundwater level measurements to gather information on the condition of the local aquifer. In some cases aquifer water levels are used as a drought response trigger.

In response to the Municipal and Industrial Drought Survey (Fall 2003), a number of water providers noted that there were many sources of information but that more timely forecasts, sufficient confidence and lead-time in forecasts to make planning decisions, and better drought information dissemination were especially important. Some of the responses received are listed below and a more complete record is found in Attachment 1.

- Concurrent monitoring of CAP/SRP drought needed
- Different forecast lead-times are needed for different planning needs, e.g. an 18-24 month lead-time on SRP and CAP allocations, 3-4 months for public information notice, 3-5 years for capital improvement project planning needs.
- Need for more snowpack monitoring in certain areas, e.g. Huachuca Mountains
- Need for more aquifer monitoring and aquifer studies to understand supply availability
- Climate data needs to be translated into information that can be used by providers for planning purposes.
- On-line, real-time, statewide information is needed on where and what impacts are occurring
- Forecasts and drought maps need to be more geographically-specific since there is a high degree of variability within the current climate divisions.
- Need to understand water use better, especially by small domestic wells

b. Potential M&I Drought Indicators

Based on the survey response and work by the Monitoring Committee, several possibilities emerged as potential drought indictors for municipal and industrial water users.

- Reservoir levels
- Water system production levels
  - This is a provider-specific indicator. Drought impacts on production would be quickly known by providers. Arizona Corporation Commission (ACC) curtailment plan triggers are related to storage levels and the ability of well production to maintain storage.
- Groundwater levels in critical areas
  - ADWR measures groundwater levels periodically and maintains a groundwater level database that may be useful for tracking groundwater levels in critical areas. However, more regular and additional monitoring of water levels would be needed to be effective.
- Evapotranspiration (ET)

- There is a direct correlation between ET and short-term municipal water demands. It may be helpful if local ET values were made available to domestic water providers and to customers to assist with short-term water demand planning and action plans. This information would be most valuable if it can be predicted and focused in areas with system capacity limitations. However, measurement and distribution of ET information may be expensive and should only be considered if economically feasible. Temperature forecasting alone may also be a possible short-term indicator
- The accuracy of summer ET values may be inconsistent because of the aerially inconsistent nature of rain during those months.

- Information Dissemination
  - Selected drought indicator information would need to be distributed to municipal providers in a consistent, understandable and timely manner. This could be done by fax, email, direct mail or other mass communication method.

c. Potential M&I Triggers

Water providers could adopt drought triggers appropriate for their service areas that would call for specific levels of action. Potential triggers could include the following.

- Reservoir Level Triggers
  - SRP, CAP and the Bureau of Reclamation already monitor the major reservoirs and these levels may be used as input to the trigger system. However, there may be a need for additional monitoring in smaller reservoirs.
- Water System Production Levels
  - Declines in production would trigger different conservation programs, similar to ACC curtailment plans. This would need to be carefully designed so that it was triggered by drought and not by a system maintenance or similar problem
- Indicator Well Triggers
  - Designated conservation activities to be implemented when pre-determined water levels are reached. An example would be the San Antonio groundwater level monitoring/trigger system and Payson's mid-January water level measurement that determines drought stage and response. Indicator wells would need to be representative of conditions in the area.
- Evapotranspiration (ET) Triggers
  - When a pre-determined ET value is reached in given areas, it could trigger a municipal water provider advisory that there could be short-term water demand increases. The provider could initiate use of emergency water supplies, or implement demand management programs. This type of trigger would be important to those municipal providers with borderline adequate water storage capabilities and/or inadequate water reserves.

4.Municipal & Industrial Drought Mitigation Strategies

This section discusses methods and strategies that water systems can implement to help minimize the negative impacts of a long-term sustained drought. Attention is given to both water supply and demand issues. Because of fundamental differences between public and private water systems, which in-part dictate the authority and resources available to each, certain methods or strategies may not be available or practical to both types of utilities. In addition, some supply side strategies may be limited by existing institutional and legal frameworks.

Importance of Planning

Having a well thought-out and documented operational plan for dealing with both standard and non-standard operating conditions is critical for public water systems. The public expects that

their water provider has such a plan in place. Long-term water supply planning can reduce a provider's vulnerability to drought. In addition, it is the water provider's responsibility to assure a comprehensive emergency operational plan is in place, before the emergency occurs, to be able to respond quickly. The planning should include extremely short-term conditions like power outages and infrastructure interruptions, as well as for longer-term conditions, like those brought on by an extended drought. Further discussion on developing and implementing a municipal water provider drought plan is discussed in Attachment 3.

Supply Side Strategies

Common water supply side measures that could be implemented include construction of additional storage facilities; acquisition of additional water sources such as by drilling new wells or purchasing additional water from nearby larger, regional water agencies or municipalities (on a long-term, or short-term, emergency type basis); maximizing existing supplies by making capacity improvements to existing wells, water treatment plants, or through groundwater recharge; and water reuse. Recovery planning needs to be part of drought mitigation recharge activities so that the full mitigation benefits are realized.

A broad water supply portfolio is critical for a utility in order to make more options available in times of shortage or to simply keep up with increasing water demands due to growth and population increase. Additional storage and wells could help a utility more effectively cope with the daily fluctuations in water demands and provide additional water for short-term peaks. Groundwater recharge would permit the utility to store excess water during periods of lower demand, such as during the winter months, and recover it during shortage or high-demand periods. Any recharge plans should include a carefully considered recovery plan as well. If other alternative, previously unused water supplies are available, such as lower quality surface water or groundwater sources, or perhaps effluent from wastewater treatment facilities, water reuse could be implemented by the construction of dual distribution systems. All these alternatives would increase the adequacy of existing supplies and infrastructure by reducing demands on existing higher quality water sources. If required, immediate-term solutions could be implemented such as water hauling or temporary pumping. However, this would be a very localized alternative and likely only used as a response to an emergency situation.

Demand Side and Efficiency Strategies

In addition to water supply side issues, it is equally important to consider demand side issues in order to maximize the effectiveness of a drought mitigation plan. Demand side strategies that could be implemented include making distribution system improvements, water conservation, landscape irrigation requirements and water restrictions, conservation inducing water rates or rate structures, and implementation of innovative water collection techniques such as gray water reuse or rainwater harvesting to help reduce water demands. It should be noted that an on-going, effective conservation program may result in the inability to achieve substantial additional conservation savings in the event of a drought. However, an on-going conservation program stretches available supplies for use in the event of drought.

Distribution system improvements could include the repair or replacement of aging infrastructure, upgrading of existing infrastructure to increase capacities, implementing a leak detection and repair program, lining or piping of canals, repair of damaged canal linings, metering, and other similar alternatives to control water losses and minimize unaccounted for water. Water conservation includes both indoor and outdoor measures, such as installation of low-flow plumbing fixtures and water-efficient landscaping, respectively. Public education programs could also be employed to distribute water conservation tips, demonstration gardens constructed to display efficient landscaping techniques, etc. Irrigation requirements or restrictions could include

restricting lawn watering between certain hours to minimize evaporation losses, odd-even watering days, or watering a limited number of days per week.

Although many of these alternatives are not necessarily short-term solutions to drought, they would be especially helpful during drought periods by reducing water demands and extending the adequacy of existing water supplies. Water restrictions are more of a short or immediate-term response to drought and, with proper planning, would only be necessary under the most severe conditions.

Further discussion and details of these supply and demand side strategies are included in Attachment 4.

5.Municipal &Industrial Recommendations

There are several key components to an effective response to drought, discussed in more detail in previous sections of this Chapter, which are summarized here. Long and short term planning, effective and timely communication, appropriate information dissemination, implementation of effective programs, adequate monitoring and long-term investments in system improvements are all essential elements of drought preparedness and response.

Information Dissemination

Dissemination of information on the condition of the selected drought indicators needs to be done in a consistent, understandable and timely manner. This could be done via fax, email, direct mail or other mass communication methods by a designated agency or committee. For example, TV stations and print media might assist with distributing weekly information relating to ET and residential landscape watering needs. A web-based drought status map, at a meaningful scale for Arizona may be useful to indicate the type and severity of drought conditions across the state. An example from Montana can be viewed at:
www.nris.state.mt.us/Drought/status/DroughtStatusMaps.html

Expanded drought planning and preparedness

Long-term drought planning including water supply expansion, system improvements, a conservation plan and other components help a provider reduce vulnerability to drought and should be considered as a requirement for all water systems. The expertise and expense necessary to develop a long-term plan may be beyond the reach of many small rural providers. Financial and technical assistance will be necessary to assist those water providers that lack sufficient resources. Emergency drought response planning is also a critical need and should be a component of a long-term drought plan. The ACC has developed a curtailment plan process that can be utilized to respond to drought conditions. The process can be reviewed at www.cc.state.az.us/utility/forms/Curtailment-Std.pdf. Approximately 40 private water providers have developed an ACC Curtailment Plan. These plans are primarily focused on emergency response, rather than adaptation or limiting the future impacts of drought. The Arizona Department of Environmental Quality requires that all municipal providers have an Emergency Operations Plan to respond to system emergencies. Consideration of integrating with or expanding on these existing requirements to include a drought preparedness component should be investigated.

A drought mitigation plan requirement should be developed that considers financial and technical resource issues, potential for drought impact and variations in size of service area populations.

For example, some systems could be given a longer time to comply if they have not experienced drought impacts, others could be required to adopt minimum requirements as an interim step, the timeframe could be shorter for larger providers, etc.

Regional drought planning and preparedness

Development of pro-active drought plans in cooperation with jurisdictions and other providers in their areas would help stretch resources and provide for a cooperative response. (See Attachment 5). To address emergency response, the State could consider establishing an Emergency Response Team to assist domestic water providers with drought emergencies. An example would be helping the utility arrange for water hauling. An objective of a regional plan could be to help support documentation of past regional drought impacts, to raise awareness across a broad area and to better prepare for future impacts. A regional approach could also help in the development of a reclaimed water system that could be used to reduce vulnerability to drought and also be available as a backup water supply for many purposes during droughts. The Local Area Impact Assessment Groups described in the Operational Drought Plan could be critical in regional planning efforts.

Increased Monitoring

Increased snowpack monitoring may be helpful in those areas like Sierra Vista and parts of the Coconino Plateau that rely on snow runoff to replenish their water systems. Increased and targeted groundwater level monitoring may be helpful in those areas experiencing drought related groundwater level and production problems including parts of Coconino, Gila and Yavapai Counties. In order to increase statewide monitoring of drought related data, providers might consider partnering with existing organizations like the Arizona Flood Warning System, which already has a network of statewide hydrological and meteorological monitoring stations. The state or other entity could take the lead in ensuring that monitoring data is provided to decision makers and to the public in a meaningful and time-appropriate manner.

Conservation options for water companies and jurisdictions

Conservation can be an important drought mitigation strategy and mandatory water use restrictions an important emergency response option for municipal and industrial water users. There are many water conservation measures and programs that will reduce water demand but programs must be implemented that are appropriate for the particular service area. This may require additional water use measurement and other research so that effective programs can be selected. Conservation may not be an appropriate drought response for some Arizona communities that already use water efficiently. The Operational Drought Plan should consider triggers for mandatory water use restrictions during times of serious drought and increasingly stringent conservation measures as drought severity increases. The Arizona Statewide Water Conservation Strategy provides detailed water conservation information and the Drought Operational Plan contains recommended drought conservation measures.

Incentives for system improvements, ordinances and other options to limit vulnerability to drought.

This topic is more fully explored in Attachment 4, Drought Mitigation Strategies.

Municipal &Industrial Attachments

1. **Summary of M&I Work Group Drought Survey and Responses**
2. **M&I Vulnerability Issues Identified in the 2003 Rural Water Resources Survey**
3. **Arizona Municipal Drought Management Plans, Curtailment Plans, and Ordinances**
4. **M&I Drought Mitigation Strategies**
5. **Developing and Implementing a Municipal Water Provider Drought Plan**

M&I Attachment 1

Summary of M&I Work Group Drought Survey and Responses

On October 21, 2003, the M&I Work Group met to discuss drought vulnerability and planning issues. Prior to the meeting, a four-page drought survey was emailed to almost 800 people on the GDTF list. The survey questions covered the general areas of Drought Vulnerability, Historic Drought Impacts, Drought Monitoring and Forecasting, Drought Planning, and Drought Response.

Survey Responses obtained at October 21, 2003 M&I Work Group Meeting:
The participants were divided up into four discussion groups. Each group discussed the survey questions and a recorder captured the responses. Their compiled discussion is included later in this section. The four groups were as follows:

Group A (providers with access to CAP, SRP or other surface water supply)
Participants: Kathy Jacobs, Chuck Cullom, Steve Davis (facilitators/recorders); Adam Miller, Stephen Rot, Bruce Hallin, Herman Bouwer, Clinton Williams

Group B (providers with access to CAP, SRP or other surface water supply)
Participants: Sandy Fabritz, Guy Carpenter (facilitators/recorders); Brad Hill, Steve Rossi, Bill Haney, Tom Buschatzke, Drew Swieczkowski, Collette Moore, Erik Filsinger

Group C (providers without access to CAP, SRP or other surface water supply)
Participants: Tom Sands, Keith Larson (facilitators/recorders); Robert Mawson, Steve Olea, Ann Elmer, Paul Lee, William Crosby, Marvin Collins, Joe Abraham

Group D (providers with access to CAP, SRP or other surface water supply)
Participants: Linda Stitzer, Ed Nemecek, Melanie Lenart (facilitators/recorders); Val Danos, Karen LaMartina, Ries Lindley, Mary Reece, Lynne Fisher, Marjie Risk, Esmie Avila, Kathy Rall

Mailed in Responses:
After the October meeting, the four-page survey was also mailed to an additional 18 domestic water providers identified as having experienced drought related challenges or located in areas of the state with the potential to be impacted.

City of Avondale*: Esmie Avila, Water Resources analyst
City of Flagstaff*: Adam Miller, Water Conservation Manager
City of Glendale*: Doug Kukino, Environmental Resources Director
City of Mesa*: Colette Moore, Water Resources
Town of Patagonia: Randy Heiss, Town Clerk/Manager
City of Tempe: Eric Kamienski, Water Resources Administrator
Bella Vista W.C.: Judy Gignac, VP/General Manager
U of A Dept. of Ag.: Stuart Hoenig, PhD.
Black Canyon Water Improvement District: Pam Massat, Chair

* denotes also attended October 21st meeting

M&I Work Group Compiled Drought Survey Responses

DROUGHT VULNERABILITY			
GROUP A	**GROUP B**	**GROUP C**	**GROUP D + mail-in**
Glendale: Access to multiple supplies limits vulnerability. Groundwater and CAP water can be substituted for SRP water but increases costs. Drought caused more use of gw and impact on AWS account. If drought impacts ability to serve then outdoor conservation will be required. ***Flagstaff:*** GW levels have declined, increasing costs. Looking at drilling new wells. Long-term strategy is to acquire sustainable water supplies. SW supplies unavailable. Are adopting a water sustainability strategy. Neighboring water system supplies have dried up, resulting in demand from customers hauling from 30+ miles. Landscapes vulnerable from reduced precip. Potential lost revenue. Issue of public perception of drought v. growth and public perception of water supply planning. ***SRP:*** can substitute GW and CAP; costs increase. ***ACC:*** noted increased vulnerability for small systems due to lack of alternative supplies.	***Peoria:*** Policy requires redundant supplies; 60% goal. Physical backup burden (wells) is on developers. ***Phoenix***: Increasing well capacity to cover surface water shortfalls. Goal of diverse water portfolio. Groundwater supply may be impacted by water quality issues. Aggressively protecting surface water rights. Need to maintain ability for SRP, CAP interconnection and flexibility of exchange. Vulnerability strongly related to the economy. Environ. regs. Impact access to supply and will increase. ADWR policies impact how to plan for recharge, i.e. ability to pump. ***Mesa:*** CAP and GW used. Goal to have enough well capacity to backup either SRP or CAP shortfall. Issue of location of demand v. location of supply. Need to increase water exchange flexibility to address drought stresses. Are meeting customer needs. Lowering water tables means reduced production and storage ability. Increasing demand.	***Sunrise/West End (NW Valley):*** Unclear if there has been a long-term impact on groundwater levels Tourism causes water supply problems in Pine and Strawberry. Repairing leaks and enforcement of curtailment plan helps. Less water is now available in the Globe area and San Carlos Apache Reservation Private wells are often not deep enough to withstand long-term drought/declines Vulnerability can be related to how deep a provider's well is and how much screened interval is left.	Surface water most vulnerable; reductions in supply and infrastructure limitations result in increased groundwater pumping. More groundwater use meets short-term needs but potential long-term impacts on water quality and possibly subsidence. Economic impacts of reduced water provider income, also tourism and ag. When demand is lower, revenue decreases, at a time when money for infrastructure is needed. Communities without groundwater have immediate impacts, including economic e.g. Williams. ***Gilbert:*** uses 45% SRP. Adequate supply now but due to drought concern, drilling 3 new wells, up from planned 5 wells in 10 years. Large financial investment in reducing vulnerability. ***Avondale, mail-in:*** Drought has not impacted ability to meet customer demands. Need more storage and production to meet peak demands. GW level has fallen. Recharge project most vulnerable because less surface water available for recharge.

DROUGHT VULNERABILITY (CONT.)	
Mail-in Tempe, Flagstaff **(Providers with access to CAP, SRP or other sw supply)**	**Mail-in Hoeing, Black Cyn. City, Patagonia, Bella Vista and Mt. Tipton** **(Providers w/out access to CAP, SRP or other sw supply)**
Tempe: SRP reduced stored sw allocation to member lands from 3 af/ac/yr to 2 af/ac/yr. Impact on "normal flow" Salt River water rights available for delivery to Class A lands in Tempe. No impact on ability to meet customer demand. Using back-up sources including excess CAP, SRP groundwater, Tempe groundwater. Stored surface water component of overall SRP member land water allocation is most vulnerable. Class A lands with later priority dates also vulnerable when below ave. runoff. CAP less vulnerable because of greater reservoir storage capacity. Outdoor residential demand increases with drought as does golf course, parks, lakes. ***Flagstaff:*** Short-term drought; forces additional use of groundwater. Long-term would have severe impact on aquifer's ability to recover to pre-drought levels; potential for subsidence, declining water levels, poor water quality. Prolonged drought after 2020 could affect ability to meet all demands. CAP most vulnerable. Peak day water storage may be affected. Prolonged drought means more expenditures on building storage capacity.	***Hoeing***: Farmers and ranchers have experienced dropping water levels due to municipal pumpage. Rural areas most at risk due to limited funds for wells and conservation. ***Black Cyn. City WID***: Water levels in wells dropped in summer of 2002, prompting capital improvements of new wells and drought emergency plan and water conservation advertising. ***Patagonia:*** Several private wells within town limits went dry. Town planning to extend service area to serve affected area. Productivity of town wells may be impacted if drought persists. Town's wells may rely on subsurface flows and would be most vulnerable. ***Bella Vista****:* Systems in shallow aquifer area have been affected resulting in difficulty maintaining sufficient storage. Some customers water native vegetation and have high use landscapes (pools and turf); system not designed for this. ***Mt. Tipton:*** Increased demand, reduced well production and aquifer depletion. Old pump, difficulty meeting peak summer demand. Need for more storage. Concern about fire protection, slow recovery time.

HISTORIC DROUGHT IMPACTS			
GROUP A	**GROUP B**	**GROUP C + mail-in**	**GROUP D + mail-in**
Glendale: offsetting reduction in SRP supplies with CAP. Increasing conservation efforts. SRP reduced allocation on 1/1/03. ***Flagstaff:*** still in drought; using more groundwater and spring run-off. Water restrictions first implemented May 12, 2002. Fall 2002, Lake Mary was 8% of capacity and unavailable as a drinking water source. ***SRP:*** still in drought. Monsoon normally does not break drought. Are planning for continuing drought/reduced delivery. Summer 2002 Roosevelt at 10% capacity and deliveries curtailed by 150Kaf. Recreational impacts on Salt and Verde Reservoirs (normal year revenues about $40 million). ESA (SW Willow Flycatcher) compliance resulted in $20 million habitat restoration project.	Consensus that drought continues. ***Phoenix:*** Historical droughts have been agricultural. SRP reductions and resultant impacts not fully understood (e.g. 1/3 cut is 250,000 af) In 1951-52 the gates were up at Horseshoe Dam, now with CAP have more flexibility. ***Mesa:*** Not much impact in meeting demand but it's a paper chase (i.e. SRP/RID exchange for SRPMIC). Potential for GPCD impact; should providers be punished for GPCD caused exceedences? Climate and reservoir storage impacts noted for several years, esp. during 2002. 1/1/03 SRP reduction. 2002 most severe in terms of lowest SRP reservoir storage levels and measured runoff in over 100 years.	***Sunrise/West End***: No impacts yet Data not available to evaluate (or predict) drought impacts Payson, Pine and Strawberry are working on a monitoring project (Preacher Canyon) involving surface and ground water. ***Bella Vista:*** Water level decreases noted during last 3 years; summer of 2000. Worst times May and June. Some problems post-Monsoon. ***Patagonia:*** Impacts first felt April-July, 2003 when well failures reported. Town has provided hauled water supply to affected people. ***Black Cyn. City WID***: Summer of 2002 was first drought impact since district formation in 1986 ***Mt.Tipton:*** Problems since 1997 with new hook-up moratoriums in '97-'98 and '00-'02.	Previous droughts have occurred in '88-'89 and '95-'96. When it rains drought potential is quickly forgotten. ***Tucson***: never felt drought impact, i.e. growth effects same as drought. Massive growth in the '70s caused supply problems but investments made in resource development and conservation. Drought will be over when there is a normal snowpack and normal rate of melt. ***BOR:*** Payson in Stage IV since mid January. Ticketed if they water gardens. ***Avondale mail-in***: Drought impact felt in 2002 when SRP reduced allocation to customers.

DROUGHT MONITORING/FORECASTING			
GROUP A	**GROUP B**	**GROUP C + mail-in**	**GROUP D**
Glendale: Timely SRP surface & total allocations, CAP ag, M&I and excess allocations all useful. Need to monitor for concurrent CAP SRP drought. Info is currently available. 18-24 month allocation lead-time desirable. ***Flagstaff:*** Small watershed/small reservoir make local forecasting important. Snowpack, spring discharge, soil monitoring needs. Need aquifer sustainability and characteristics info.1-2 years advanced warning helpful. Need $ for technical and public efforts. Concern about forecast accuracy. ***SRP:*** Ongoing meteorological studies and data necessary ***ACC:*** Small providers respond day to day; need communication and appropriate tools for drought prediction. Need to turn data into information. ***Tempe:*** monitors groundwater levels, SRP allocation and SRP PROP, CAP reports, USGS streamflow data, SNOTEL, climate studies. Info is currently available and sufficient. 12-18 mo. lead-time necessary.	***Peoria:*** Reliance on SRP/CAP water reports and BOR on Colorado. How are predictions pulled together? High uncertainty. Need better data understanding. Relationship to CIP and development process. ***Mesa***: Upper Basin forecasts and SRP briefings done in October. CIP planning needs 3-5 year forecast, budgeting for water purchases need 1-2 years. Info on watershed health and extent of water hauling helps explain impacts to citizens. ***Phoenix***: High confidence in SRP forecasting and monitoring. Need more timely info on when, how and duration of possible CAP cuts. BOR needs to look at their shortage allocation methods. Need on-line, real time, statewide info, "PIO" component, and when, where and what impacts, including enviro. Non-drought need info annually, in drought need real time info and 1-2 yr. forecasts. Need geographically-specific drought maps for Valley providers. Need info on data accuracy. Need to monitor water quality, plume migration changes.	***Sunrise:*** Need to separate growth impacts from drought impacts. ***Gila County***: Need more water level monitoring and info sharing by the state outside of the AMAs. Need monitoring wells and data collection under the Rural Watershed Program Need for water storage information at Blue Ridge reservoir and flow information for Tonto Creek, East Verde and major natural springs. ***Patagonia:*** Need long-term forecasts on length and severity of drought. Need static water level measurements in nearby wells. Extent of available info not known. Need 2-5 yr. preparation lead time. ***Bella Vista***: Snowfall is best indicator but snowpack not being monitored. Only groundwater is used so preparing for drought is more difficult. ***Hoenig:*** Need long-term predictions by area and intensity. 6-12 mo. lead-time needed. Info. is insufficient. ***Black Cyn. City WID:*** Weekly water level elevations monitoring. ***Mt. Tipton:*** Use on-line drought information to increase awareness. Already doing all possible; situation critical.	Reliance on SRP and CAP. Provide real-time flow information. ***Gilbert:*** monitors groundwater levels (but water levels have been rising due to farmland retirement). Need for longer-term forecasts, friendlier website projection info. Usability of BOR forecasts is low. ADWR should take the lead. Need at least one-year notice for CAP orders. Need forecasts by watershed due to high degree of variability. ***Tucson***: Exempt well pumpage needs to be monitored, at least in AMAs since they represent a usage component. CAP recharge is a big supply component but low priority, subject to quickly being shut off. ***Avondale:*** Drought triggers based on supply-demand discrepancy. Need hydro information and 3-4 month lead-time to prepare for public notice and 1 year to prepare for surface supply orders. ***BOR:*** Payson determines drought stage based on measured mid-January water level. END Insight packet reservoir storage information useful for planning.

DROUGHT PLANNING			
GROUP A	**GROUP B**	**GROUP C**	**GROUP D**
Glendale: preparing a drought plan. Need info to conduct a proper risk assessment, e.g. frequency of shortages, depth of allocation cuts, flexibility of state regulations during drought, cooperative opportunities between water use sectors, SRP, CAWCD drought contingency plans. ***Flagstaff:*** Has drought plan. Drought is norm so continuous water restrictions in place. City has long-term water sustainability strategy. Need for assistance with supply augmentation and assessment and information dissemination. Helpful if state could annually assess watersheds and issue a well-publicized statement of watershed susceptibility to drought. ***SRP:*** incorporates drought in planning. ***ACC:*** Need to help small providers plan and respond to shortages. New rate cases require meters, reporting of water pumped and sold. Losses greater than 10% must be addressed in rate cases.	***Mesa:*** has a drought plan. City council implements plan, stages advance in severity. Water sales impact the entire city budget. ***Peoria:*** drought plan based on San Diego and Phoenix. City manager implements plan. ***Phoenix:*** plan implemented by Water Service Director. Surcharge to make up for water sales decline. Cities need to know how sectors would choose to reduce water and have the ability to pull back non-potable water for potable use. Public perception issues about turf users; they have grandfathered rights and no effluent use curtailment during drought. Issues about ADWR requirements including need for possible drought exemptions, e.g. use of credits in relation to 4' recovery well declines and Assured Water Supply 1000' restriction. If you know you have a drought pumping exemption, it impacts capital planning. AWBA needs more info on available recovery infrastructure during drought.	Key issue for many is separating drought from growth issues. ***Sunrise:*** often considers deepening existing wells or drill new wells; existing wells along mountain fronts are replenished primarily from rainfall and can't be deepened. ***Gila County***: Need statewide drought condition info that identifies problem areas. Need credible regional groundwater information, e.g. from regional aquifer monitoring wells. Private well owners often do not want their information published. State could help providers initiate conservation programs (e.g. internet links to Valley programs like "Water use it wisely"). Desirable to tailor programs to fit local areas. ***Safford:*** Has a drought/curtailment plan and a conservation program. Resistance to water use restrictions. Target middle-school students?	***Chandler and Tempe*** working on drought plans. ***Mesa*** adopted Oct. 13, 2003. Wants ADWR info on how the AWS drought pumping exemption will be managed. ***Gilbert:*** plan calls for percentage reductions based on surface water supply availability. ***Tucson*** has a drought response program. City Council can declare an emergency. 50-year plan considers drought. What are other sectors doing? Drilling exempt wells in service areas threatens groundwater supply. ***Avondale*** is adopting mandatory conservation standards and will adopt a drought plan soon. Info on groundwater conditions is needed. Drought triggers needed for wells. Need to know sustainability of supply. Observation that by 2020 many cities will be facing a drought-like scenario as the norm i.e. limited supplies

DROUGHT PLANNING (CONT.)			
Mail-in Tempe		**Mail-in Black Cyn. City WID, Bella Vista, Patagonia, Mt. Tipton**	**Mail-in Tucson**
Has a drought plan with voluntary measures and targeted reduction at city facilities and urban SRP irrigation accounts. Includes elimination of winter overseeding at city facilities, public info campaign for similar voluntary participation by others. Other exterior programs. Second phase drought plan being developed to include drought declaration stage and some mandatory measures. Planning done in house with assistance from other agencies. Need general outline of steps CAWCD would implement if AZ's Colorado River entitlement were reduced.		***Black Cyn. City WID***: adopted a five stage Drought Emergency Plan June, 2002. Level 1 triggered by "noticeable drop" in water levels. Response is voluntary for levels 1 and 2 and expand to mandatorywater use restrictions, moratorium on new connections and rate increases. ***Bella Vista:*** has a curtailment plan for south system. ***Patagonia:*** needs aquifer level info, and technical assistance to develop drought and conservation plans and for grant process facilitation. ***Mt. Tipton:*** Have an ACC drought curtailment plan. Education is key. Need information on landscaping, analyzing aquifer conditions	Key elements of Tucson's drought procedures are operational responses, declaration of water emergency, mandatory restrictions, resource planning to minimize impacts.

DROUGHT RESPONSE			
GROUP A + mail-in	**GROUP B**	**GROUP C + mail-in**	**GROUP D**
Flagstaff implemented aggressive conservation programs in summer of 2002 including rate structure. ***Flagstaff mail-in:*** important to ensure public is well educated about problem. Can assess surcharges for non-compliance with restrictions. Some measures can be accomplished by communities but require additional resources that may be difficult for small systems. Question of cities using drought in a political context i.e. conservation message gets more attention in a drought. ***Glendale mail-in:*** Public education and trust is key. City has conducted audit of Parks department (largest internal user), deficit irrigates parks, distributes conservation info and stepping up water waste response. Looking to store reclaimed water. First augment reduced supplies (e.g. recharge credits) and maintain sufficient well capacity, 2nd encourage demand reduction, 3rd mandate restrictions.	***Phoenix:*** Phase 1, 1-5% mandatory reduction by city, 5% voluntary for customers. Need to separate drought campaign from standard conservation message and target businesses. Phone survey to customers to know if they are responding; questions boil down to are we in a drought and have you done anything to reduce water use. ***Peoria*** similar with increase in conservation message ***Mesa*** in Stage 1; city reduction, HOA newsletter information to not overseed. Reduce water use at city facilities. Change source water and manage supply. What's the right time to mandate restrictions? Media interaction very important and sector-specific messages.	***Safford***: has a pro-active conservation program developed by contacting Valley cities. It's a model program for small towns. ***Black Cyn. City WID***: Drought emergency plan with water use restrictions. ***Bella Vista:*** Constant conservation education, personal letters to large users, participation in Upper San Pedro Partnership. Trying to identify additional physical resources. ***Patagonia:*** measures static water levels and compares to historic water level data. Town is developing additional supplies and storage facilities and capacity, could implement a water use restriction plan and added two additional blocks to rate structure. ***Mt. Tipton:*** curtailment plan requires customer conservation, use restrictions**.** Encourage Xeriscape, post Drought Task Force and graywater use information. Have a pending conservation rate case. Trying to obtain additional storage capacity.	***Gilbert:*** has a drought plan; has implemented Stage 1, triggered at 10-20% reduction in SRP supply. ***BOR:*** Payson has a conservation ordinance, has been in Stage 4 since beginning of 2003; has been in other stages for the last 2-3 years. Need a statewide education and information program and need to maintain a long-term perspective. ***Gilbert, Mesa, Phoenix:*** ask users to reduce winter overseeding. Gilbert has commitments to not overseed 7 million sq.ft. ***Tucson***: When reservoir levels are at 60% emergency water waste provisions are implemented. Wish list: increase water rates, reduce agricultural subsidies during drought, mining and industry need to do their part, moratorium on well drilling during drought, statewide effluent reuse campaign, potable water should not be used in toilets.

DROUGHT RESPONSE (CONT.)			
Tempe mail-in			**GROUP D and mail-in**
Capital improvement projects to increase back-up groundwater production capacity; wells, SRP well connections, well rehabilitation. Use excess CAP, expand reclamation facility and develop new reuse sites. Voluntary water reduction, public info and target city parks. Eliminate overseeding, conservation rate structure.			***Avondale:*** plans curtailment of outdoor watering during midday and no fountain use. Additional water supplies, water rate structure, conservation and use restrictions and fixed statewide educational program useful. ***Tucson mail-in***: uses effluent directly and recharges. Makes up 8% of supply. Reduce peak demand with media blitz. Statewide publicity would have a greater impact. Monitoring and reporting on exempt wells in service areas would help determine impact.

M&I Attachment 2

M&I Vulnerability Issues identified in the 2003 Rural Water Resources Survey

As a part of the ADWR's 2003 Rural Water Resource Study, customized survey questionnaires were sent to nearly 600 water providers, jurisdictions, counties and tribes outside the AMAs. Surveys were sent to 496 water providers, 54 municipalities, 23 tribes, and 15 counties. Survey responses were received from 114 municipal water providers, 22 municipalities, 3 tribal entities and 10 counties. Twenty-three additional responses were received from miscellaneous types of systems and are not included in the results described here. While the response rate is considered good, responses are still limited and do not represent all areas of the state equally. The responses are summarized below:

Municipal Water Provider Responses:

This group included 86 private and 28 public and quasi-public water providers. Nearly 40% of the providers had been affected by the drought, but only 16% had a drought plan. Of the 46 systems that had been affected by drought, 43 reported an increase in potable demand and 11 reported a reduced supply of potable water. When asked for specific system impacts related to drought, the 46 affected respondents reported that:

28 had experienced lowered groundwater pumping levels
32 had increased peak water demands
8 were not able to meet peak water demand
4 were not able to meet their general water supply needs
4 had experienced a reduced supply of surface water
3 indicated trucking of water was required to meet customer needs although 5 reported that trucking water is a normal part of operations

In response to what type of assistance the providers would find useful in preparing for future droughts the responses were:

40% indicated increased system storage capacity
32% indicated ability to charge higher fees for higher volume deliveries
26% indicated a drought-triggered conservation program
25% indicated ability to restrict deliveries to customers during droughts
20% indicated more advance warning of drought conditions
10% indicated the ability to distribute current climate info to customers

Jurisdictional Responses:

These included some 22 responses from rural area cities and towns that operate domestic water systems. When asked if they had been impacted by the drought in 2002, 45% replied in the affirmative. Only five jurisdictions reported having a drought response plan. When asked what kind of impacts they had experienced, the cities and towns replied as follows

27% experienced an increase in potable water demand
27% experienced reductions in available potable water supplies
27% experienced lower groundwater pumping levels
18% experienced surface water supplies
None of the 22 Jurisdictional respondents reported that trucking of water was necessary to meet customer needs.

When asked what type of assistance they would find useful in preparing for future droughts, the 22 cities and towns responded as follows:

50% indicated drought-triggered conservation programs
41% indicated ability to charge higher fees for higher volume deliveries

36% indicated more advance warning of drought conditions
23% indicated the ability to distribute current climate info to customers
23% indicated the ability to restrict water deliveries

County and Tribal Responses:
These included responses from ten counties, two tribes and one tribal district. When asked if they had been affected by the current drought, 60% of the counties and all three of the tribal respondents replied in the affirmative. In response to what types of affects they had experienced, they responded as follows:

3 counties and one tribe experienced an inadequate supply of potable water
5 counties and all tribal respondents experienced an inadequate supply for grazing and wildlife
2 counties and one tribe experienced an inadequate supply for fire suppression
4counties experienced significant impacts from bark beetles

The counties and tribes were also asked what type of assistance would be useful to them in preparing for future drought conditions. County suggestions for drought planning assistance included:

- ADWR support in preparing a county drought plan
- Coordination of planning efforts
- Access to more drought resistant water supplies
- Increased water storage and access capability
- Identification of specific county areas where drought conditions have significantly affected water supplies
- Drought status presentations by ADWR to their Board of Supervisors and community groups
- Hydrological updates throughout the state to fill in information gaps
- Determining the committed demand for various hydrologic basins in order to assess water supply adequacy
- Pre-packaged water conservation public education program
- Help in developing a water conservation plan
- Help with regulating developer lot splits

Tribal suggestions for drought planning assistance they would find useful included:

- Developing and implementing a range management plan
- Better planning, better water storage and better conservation
- Alternate water source development
- Providing or improving water hauling capabilities

M&I Attachment 3

Arizona Municipal Drought Management Plans, Curtailment Plans, and Ordinances

BACKGROUND

Several years of less than average rainfall have created drought conditions in most of the Southwestern United States. These years of successive drought have prompted a decrease in surface water resources, specifically Salt River Project water, in the Phoenix Active Management Area (AMA). In an effort to plan for times of drought, seven cities in the Phoenix AMA (Gilbert, Mesa, Peoria, Phoenix, Glendale, Chandler and Scottsdale) have revised existing or drafted new Drought Management Plans and Tempe is in the process of adopting a plan.

The underlying goals of all of the Drought Management Plans is to:

1) Protect public health and safety;
2) Provide enough water to cover basic water demands of citizens;
3) Minimize economic impacts of drought; and
4) Distribute impacts of drought amongst all sectors.

Each of the plans consists of four stages that increasingly restrict water usage in all sectors of the water using community: 1) municipal department uses, 2) residential customers, 3) commercial customers and 4) industrial customers. The following paragraphs summarize the basics of the drought management plans, but there are some variations to each plan.

First Stage of Drought

Every drought management plan includes an intensified public education program emphasizing the need for water conservation and most request that customers voluntarily reduce consumptive use by 5% during the first stage of the drought. Each municipality has mandated a 5% or unspecified decrease in water consumption for all municipal operations. All of the cities recommend conserving water by changing habits including, but not limited to: restricting car washing to hoses with nozzles or commercially with recycled water, ending of sidewalk washing, alternating watering days and hours, prohibition of misters for outside cooling, no overseeding of winter lawns, no water features unless they use effluent. The City of Phoenix's plan is the only one that defines a base use volume of water for its customers, so that a reduction can be calculated. This volume is 4,488 gallons from October through May and 7,480 gallons from June through September.

Second Stage of Drought

Most of the drought plans make the voluntary 5% reduction described in Stage 1 mandatory and require that all municipal departments decrease water consumption by 10%. Public education efforts are intensified once again.

Third Stage of Drought

All restrictions in Stage 2 may be mandatory and include a decrease in customer consumption by 10%, municipal departments are made to decrease water consumption by 15%. Further water use

reduction on landscape irrigation to one day per week. This stage also reduces the issuance of construction meters and commercial building permits.

Fourth Stage of Drought

All restrictions in Stage 3 are mandatory and most include a decrease in customer consumption by 15%, municipal departments are made to decrease water consumption by 20%. Further reductions on water use as needed to balance supply with demand are to be achieved with more limits on landscape irrigation. As a last resort, all cities have mentioned a moratorium on building permits if current demands could not be met.

TRIGGER POINTS

Each of the drought plans differs on what triggers a stage in drought plan implementation.

Town of Gilbert

The trigger points for the drought stages for the Town of Gilbert are based on decreases in surface water allocations.

First Stage of Drought:	10-15% reduction in surface water allocation.
Second Stage of Drought:	16-25% reduction in surface water allocation.
Third Stage of Drought:	26-40% reduction in surface water allocation or inability to meet customer demand using other water resources.
Fourth Stage of Drought:	More than 40% decrease in surface water allocation, water demand cannot be met, or "catastrophic water supply failure occurs".

City of Scottsdale

As described in the Town of Gilbert's drought management plan, the trigger points for implementation of the City of Scottsdale's Drought Management Plan is also dependent on reductions of surface water allocations, specifically Salt River Project (SRP) and Central Arizona Project (CAP) waters. The drought management plan can be triggered into effect at any time to protect public health and welfare of Scottsdale citizens.

First Stage of Drought: No exact reduction volume is specified for the commencement of Stage 1.

Second Stage of Drought: A Stage 2 drought may be declared upon any or all the following conditions:

1) "SRP surface water deliveries will be reduced to a level which results in insufficient water supplies being available to meet 95% of the water demand for the year prior to the initial drought declaration".
2) Available CAP reductions are 10% less than the volume of water ordered by Scottsdale the previous year
3) Any combination of water supply reductions that causes a 10% decrease in available water resources.
4) It is determined that such a declaration is required for the general health, safety and welfare of Scottsdale residents.

Third Stage of Drought: As in stage 2, the Scottsdale's plan is dependent on further reductions of the above mentioned water resources.

1) SRP water reduction to 90% of water demand of the prior year.
2) Available CAP reductions of 20% less than the prior years CAP order.
3) Any combination of water supply reductions that causes a 15% decrease in available water resources.
4) It is determined that such a declaration is required for the general health, safety and welfare of Scottsdale residents.

Fourth Stage of Drought: As in stage 3, the Scottsdale's plan is dependent on further reductions of the above mentioned water resources.

1) SRP water reduction to 85% of water demand of the prior year.
2) Available CAP reductions of 25% less than the prior years CAP order.
3) Any combination of water supply reductions that causes a 20% decrease in available water resources.
4) It is determined that such a declaration is required for the general health, safety and welfare of Scottsdale residents.

City of Peoria

As with the other plans, implementation of the drought management plan for the City of Peoria is based on water reductions surface water and in situations when water demand cannot be met and/or system failure.

First Stage of Drought: SRP or CAP water allotments may possibly be reduced.
Second Stage of Drought: The probability that Demand cannot be met by the City of Peoria.
Third Stage of Drought: Demand cannot be met by the City of Peoria.
Fourth Stage of Drought: A major failure occurs for any water system providing water to City of Peoria, including Peoria, SRP or CAP

City of Phoenix

City of Phoenix's trigger points are also implemented upon reductions in SRP and CAP surface waters, as well as in the occurrence of water system structural failures or catastrophic incidents.

First Stage of Drought: SRP or CAP announces reductions in allotments to Phoenix significant enough to trigger Stage 1.
Second Stage of Drought: SRP or CAP reduces allotments to Phoenix.
Third Stage of Drought: SRP or CAP further reduces allotments to Phoenix.
Fourth Stage of Drought: Can be declared based on the severity of the water crisis, to protect public health and safety.

City of Mesa

City of Mesa's trigger points are also implemented upon reductions in SRP and CAP surface waters, (including Indian lease water) and when water demand cannot be met.

First Stage of Drought:	Declared when a surface water shortage is predicted or occurs. No exact reduction volume is specified.
Second Stage of Drought:	SRP combined deliveries cut to less than 1.5 acre-feet/acre and/or CAP subcontract and Indian lease water is cut to an amount equal to or less than 80% of the amount used in most recent non-drought year.
Third Stage of Drought:	SRP combined deliveries cut to less than 1.0 acre-feet/acre and/or CAP subcontract and Indian lease water is cut to an amount equal to or less than 60% of the amount used in most recent non-drought year.
Fourth Stage of Drought:	Declared when water deliveries are insufficient to meet projected water demand.

City of Glendale

City of Glendale's trigger points are implemented based on availability of surface water supplies and on the capability of providing water service to customers.

First Stage of Drought:	Declared when drought conditions exist on the watershed(s) that provide surface water and when "the respective water district" is either considering or cuts allocations. The city is capable of providing normal water service.
Second Stage of Drought:	Declared when total water allocations are cut and the City anticipates it may not have sufficient resources to meet normal water demand.
Third Stage of Drought:	Total water allocations are cut and the City is able to provide 90% of normal demand.
Fourth Stage of Drought:	Declared when city projects a 20% or greater shortage.

City of Chandler

City of Chandler's trigger points are based on actual or predicted surface water shortages.

First Stage of Drought:	Surface water shortage is predicted.
Second Stage of Drought:	SRP deliveries cut 40% and/or CAP supplies are cut 10%
Third Stage of Drought:	SRP deliveries cut 50% and/or CAP supplies are cut 15%
Fourth Stage of Drought:	SRP deliveries cut 60% and/or CAP supplies are cut 30%. Significant possibility of reduced supplies to meet following year's demand and unlikely that City can deliver sufficient water to meet all demands.

ENFORCEMENT ACTIONS

Gilbert Stage 1 penalties include educational letter and/or home water audit for water wasting violations. Stage 2 will invoke penalty options on top of the educational letter. During Stage 3, in addition to penalties from Stage 2, will start having drought surcharge for water wasting, which will be set by the Town Council. These carry forward to Stage 4 of a drought.

The City of Scottsdale has not specified what actions it would take to enforce the drought management plan.

City of Peoria will implement enforcement of the drought management plan after stage 2 is declared. Any violation will be a misdemeanor and the violator is subject to penalties or administrative actions. It is unclear what administrative actions might be for Peoria, but other drought plans include water conservation educations classes as penalties.

The City of Phoenix staff will direct resources to enforcement, but usually not take any actions until Stage 2 of a drought. Enforcement will consist of an order to correct the violation, (i.e. water in the street) within a specified time frame. If the violation is not corrected, water service may be disconnected and the owner may face additional fees. This enforcement action will be carried through the rest of the stages.

The City of Mesa increases voluntary demand management measures and a stepped up public awareness program for Stage 1 and 2. In Stage 3, Mesa requires mandatory demand management measures, e.g. major water users may be required to develop a water conservation plan and civil penalties may be implemented for wasting water. In stage 4, the measures implemented during Stages 1-3 and additional measures may be implemented. Additional measures include mandatory water use restrictions and limiting new connections.

During the first two drought stages, the City of Glendale works closely with affected city departments to ensure compliance with the municipal water use restrictions. Active enforcement begins with Stage 3, when mandatory requirements are enacted. Program includes staff patrols and investigation of customer complaints of improper water use. Staff may issue civil citations, which can result in fines. Fines are incorporated into customer service fees and failure to pay may result in termination of service.

The City of Chandler may propose a “water deficiency rate surcharge” ordinance in Stage 4. Stage 4 mandatory usage reductions are enforced through Chandler’s City Code. Any person found to be in violation is guilty of a misdemeanor and can be fined up to $2,500 or subject to up to six months imprisonment.

SURCHARGES

Drought negatively impacts water revenues as a result of conservation. Negative financial impacts also occur when costs of treating water, purchasing water or pumping groundwater increase as a result of the drought. The City of Phoenix has established a system of fines and surcharges related to violators of the drought management plan that will provide the financing to pay for the additional public education and to purchase new water resources needed to alleviate the drought. There is no set schedule of surcharges, but they would create a disincentive for water use to assist in equalizing demand with supply.

The City of Scottsdale also discusses imposing drought surcharges, but has not described them in detail.

The City of Peoria’s drought plan identifies a surcharge of 125% or higher of the base water rate, which is only applied to water used above a pre-defined target monthly amount for each class of user.

The City of Mesa may implement a drought surcharge in a Stage 4 drought and increase water rates beginning in stage 3. Its plan does not specify the amount of the surcharge or rate increase.

The City of Glendale imposes a drought surcharge in a stage 4 drought for water used above a base amount.

The City of Chandler may propose a "water deficiency rate surcharge" ordinance in Stage 4.

SUMMARY

The Drought Management Plans of the municipal providers in the Phoenix AMA are similar in goals and methods to attain water conservation during critical times. Variations in the plans include when the drought stages go into effect, what causes the plans to go into effect, enforcement of the plans and what enforcement actions will be. All plans do not include specifics regarding how water conservation savings are going to be gauged and exactly how enforcement of the plan will take place. It is understood that this lack of specificity gives the municipality the latitude required to continue operations through a difficult period, allowing enforcement actions and rate surcharges to be set according to the needs of changing conditions as the drought progresses.

CITY OF FLAGSTAFF WATER CONSERVATION ORDINANCE

The City of Flagstaff City Council recently enacted an ordinance to implement a long-tern water resources sustainability strategy for water conservation to ensure adequate water availability for the future and during times of emergency. The cornerstone of the ordinance is the requirement that landscape irrigation at all times (drought conditions and normal conditions) is restricted to evening hours and limited to three times per week based on even and odd days. Other blatant forms of water waste are prohibited. Golf course irrigation is permitted only with reclaimed water.

The second stage of the water conservation program, termed "Water Emergency" is triggered when water demand exceeds total production capacity for five consecutive days. In addition to the requirements in Stage I the following water uses are prohibited:

- Washing paved areas
- Use of potable water for filling swimming pools, spas, and fountains
- Use of potable water for major construction activities

Water rates are increased to 150 percent of the established rate for consumption between 10,000 and 15,000 gallons per month, and 200 Percent of the established rate for water consumption greater than 15,000 gallons per month. Commercial rates are also increased.

The third stage of the water conservation program, termed "Water Crises" is triggered when water demand exceeds production capacity and the amount of water in storage may impair fire protection for the City. In addition to the requirements in Stage II, the following water uses are prohibited:

- Any outdoor water use
- Use of fire hydrants except by authorized government agencies

Enforcement of the conservation measures is achieved through the use of surcharges placed on the bills of customers not in compliance with the measures ($25 for Stage I, $50 for Stage II, $100 for Stage III). Surcharges double for repeat violations.

Arizona Corporation Commission – Approved "Curtailment Tariffs" for Private Water Companies

Private water companies regulated by the ACC are required to have an approved Tariff in place in order to enforce mandatory water use curtailment plans during a drought or other water system emergency. Approximately 35 curtailment tariffs are in place for utilities located in different areas of the state. In the last year, the ACC has begun requiring all companies to implement a curtailment tariff in conjunction with any new water rate case or expansion of a Certificate of Convenience and Necessity (CC&N). This new requirement is in response to the current drought and recent water shortages in several water small systems; shortages that may or may not be related to drought conditions.

Curtailment tariffs (CTs) differ from the drought plans implemented by several Phoenix area cities in several significant ways. First CTs are designed primarily to mitigate the impacts of severe water shortages in small systems supplied primarily with groundwater. Second, the tariffs contain very specific trigger points that require the utility to take specific actions to implement water conservation measures. Therefore, CTs are not as proactive as many municipal drought plans in laying out a course of action geared to avoiding mandatory rationing of water uses by customers. CTs do however, grant a private water company the necessary authority to curtail water use to avoid widespread water outages across the water provider's service area.

The ACC provides on it's website and application form and a standard curtailment tariff water companies may apply to have put in place "as is." Some companies have modified the standard CT to fit the utility's specific system needs. Most companies have adopted the standard tariff. The standard CT is comprised of four Stages with prescribed trigger points and actions the utility must take to reduce customer water use or augment water supplies. The four stages are summarized below:

Stage 1 - Water Company is able to provide 100 percent of water demand.

Stage 2 – Company cannot supply more than 80 percent of daily average demand and has identified issues such as a steadily declining watertable, increased well drawdown, poor water production, creating a reasonable belief that the provider will be unable to meet anticipated demand.

Restriction: Company may request customers to voluntarily reduce water consumption by 50 percent. Outside watering should be limited to essential water. Company is required to notify customers by written notice delivered to each customer.

Stage 3 – Company's total storage or well production has been less than 50 percent of capacity for at least 24 consecutive hours.

Restrictions: Company shall request customers to voluntarily employ conservation measures to reduce consumption by 50 percent. All outside watering should be eliminated, except livestock watering.

Notice Requirements: Same as Stage 2, in addition, Company shall post signs within the service area showing the curtailment stage. Company shall notify the ACC at least 12 hours prior to entering Stage 3.

Once Stage 3 is entered, Company must begin to augment supply by either hauling water or through an emergency interconnect with an approved water supply.

Stage 4 – Company's total storage or well production has been less than 25 percent of capacity for at least 12 consecutive hours.

Restrictions: Company shall inform customers of mandatory water use restrictions described below. Failure to comply will result in customer disconnection after written notice is provided. Mandatory water use prohibitions include:

- All outdoor irrigation
- Vehicle washing
- Use of water for dust control
- Use of misting systems
- Filling of Swimming pools, spas, or fountains
- Restaurant patrons served water only upon request
- Any other water intensive activity

Notice Requirements: Same as Stage 3

SUMMARY

Curtailment Tariffs enable a private water company in Arizona to enforce mandatory water restriction measures in the event of serious water supply shortages due to drought impacts or water system emergency. They provide some guidance and requirements for water providers regarding implementation of appropriate water conservation and augmentation strategies. However, a Curtailment Tariff should not be considered a comprehensive drought planning strategy. Private water companies having a CT could still benefit from additional information and assistance in deal effectively with long-term drought impacts to water supplies to reduce drought vulnerability.

Navajo Nation Drought Report and Drought Contingency Plan – 2002

The Navajo Nation is a relatively dry area of the State prone to periodic drought conditions. Therefore, the Navajo Nation has been involved extensively in drought planning since the early 1980's, producing several drought planning documents and contingency plans. This section summarizes the Navajo Nation Drought Report and Drought Contingency Plan – 2002, produced cooperatively by the Navajo Nation, the Bureau of Land Management, and the Bureau of Indian Affairs.

DROUGHT MONITORING

Due to the large size of the Navajo Nation (about the size of West Virginia), drought conditions can vary widely across the area. Hence, the plan highlights the need for improved drought monitoring procedures to account for differences across the area, and recommends specific monitoring procedures be put in place. The plan also describes four drought stages based on SPI levels:

Normal Conditions: SPI > 0.0
Drought Alert : SPI 0.0 to –0.99
Drought Warning: SPI -1.0 to -1.49
Drought Emergency SPI <-1.5

The Drought Monitoring strategy described in the plan is an improvement on past procedures. First, the six-month SPI developed monthly by the NDMC will be disseminated to a variety of Navajo Departments and organizations. Then, specific SPIs will be developed for the three major climatic regions comprising the Navajo Nation.

The plan assessed the drought vulnerability of the following sectors:

- Domestic Water Haulers
- Public Water Systems
- Farmers
- Ranchers

- Recreation and Wildlife

VULNERABLITY OF MUNICIPAL WATER USERS AND PROVIDERS

There are approximately 237 public water supply systems on the Navajo Nation supplied from about 370 wells. Approximately 25 percent of households are not connected to public systems and depend on water hauling. Of the 237 public systems, many are dependent either entirely on wells in shallow alluvial aquifers or are more than 50 percent dependent on alluvial wells highly vulnerable to drought.

Per capita municipal water use on Navajo lands is currently very low, ranging from 10 gpcd for those hauling water to about 100 gpcd for those served by public water systems. Therefore, conservation as a drought mitigation measure will likely not result in a dramatic reduction in water use and is therefore not a focus of the plan.

A high priority for the proposed mitigation measures recommended in the plan to is to ensure that vulnerability is reduced in public systems dependent on alluvial aquifers and those systems where a high percentage of people obtain water by hauling water. Another conclusion of the study is that many systems are highly vulnerable to drought because they lack sufficient storage. The plan developed specific recommendations on system storage levels, well system improvements, and water system inter-ties to alleviate system vulnerability. Of the total recommended drought mitigation program expenditure of $205 million, $160 million was recommended for public water system improvements.

SUMMARY

The plan includes specific drought responses for various Navajo Nation Departments and Programs during the four drought stages. The primary focus for drought mitigation for municipal systems is a capital improvement program that includes the construction of new wells, additional storage and other system improvements.

M&I Attachment 4

DROUGHT MITIGATION STRATEGIES

INTRODUCTION
This section discusses methods and strategies that water systems in Arizona can implement to help minimize the negative impacts of a long-term sustained drought. Attention is given to both water supply and demand issues. Because of fundamental differences between public and private water systems, which in-part dictate the authority and resources available to each, certain methods or strategies may not be available or practical to both types of utilities. However, sufficient alternatives are discussed to permit either type of utility to develop an effective and workable strategy to cope with drought.

SUPPLY SIDE STRATEGIES
Three water supply issues are important for any water utility. First, the utility must have access to and maintain a large enough water supply to reasonably meet the needs of its present and expected future customers. Second, it should receive this supply from a variety of sources. And third, it must have the necessary facilities and infrastructure in place to deliver this water to its customers. These items are especially important in times of drought. A broad water supply portfolio is critical for a utility in order to make more options available in times of shortage, or to help it simply keep up with increasing water demands due to growth and population increase. Dependency on one source of supply is risky. If something should happen to that supply, such as through contamination or reduction in quantity (due to drought, for instance), the utility could find itself in a very difficult, perhaps even disastrous, situation.

A number of methods and alternatives are available for a utility to not only increase the quantity of its available water supply, but also to increase the number of sources from which it receives its supply. In most communities, all water resources that are readily available have been developed to their maximum potential. As population increases and growth continues at a very high rate for many Arizona communities, new supplies will certainly be needed to keep pace with demands. Alternatives that once seemed impractical or uneconomical may eventually seem very attractive.

Although increasing water supply to satisfy ever increasing demands is perhaps a utility's single biggest concern, this issue is beyond the scope of this section to address. Instead, efforts will be focused on increasing the breath and depth of a utility's water supply for the purpose of helping reduce its vulnerability to drought.

1. Increased Storage Capacity
    a. Storage Tanks

    Storage tanks are generally constructed of concrete or steel and may be buried (concrete) or above ground (concrete and steel). The presence of storage facilities in a distribution system does not increase a utility's available water supply by making available new water sources, but provides the utility with a great deal of flexibility in the operation of the system. This can prove to be very helpful in times of drought. Storage facilities generally provide three major benefits: (1) they permit a utility to equalize its source production, (2) they enable a utility to more effectively cope with and manage daily fluctuations in water demands, and (3), they

provide additional water for short-term peaks and fire protection. Each of these items are briefly discussed below.

Equalization of source production is achieved by discharging water from a production facility, such as a water treatment plant or well, into a storage facility at a relatively constant rate over time. If a utility has adequate storage in place, short-term peaks and fluctuating water demands in the distribution system can be adsorbed by the storage facilities, instead of the utility having to continuously adjust the production rates of its sources to match these demand patterns. Because the discharge rate from the sources may be more continuous over time, it generally is lower as well.

The ability to equalize source production is advantageous during drought situations because it may extend the adequacy of existing supply facilities by reducing the required production rates of these facilities. This would leave more of a facility's existing capacity available for use during drought periods, when water demands tend to be greater than those experienced during equivalent non-drought periods.

Additional storage would also make more water available for fire protection, which also could be a critical need during drought situations, especially in many of the higher elevation communities in Arizona. The numerous large forest fires experienced in Arizona over the past few years are evidence of the extreme fire danger prevalent during droughts.

b. Groundwater Recharge

Groundwater recharge is an increasingly popular practice in Arizona and is a relatively inexpensive method to provide seasonal or long-term storage for large quantities of raw water. Groundwater recharge is a mechanism by which water is supplied to an aquifer, typically via infiltration from recharge basins or by injection through wells, and then usually extracted at a later date through recovery wells. An attractive feature of groundwater recharge is that it permits a utility to store excess water during periods of lower demand, such as during the winter months, and recover it during shortage or high-demand periods. All groundwater recharge facilities in Arizona must be approved by ADWR and the owner must obtain an Underground Storage Facility permit from them in order to operate the facility and receive credit for the water recharged. If the recharge supply is CAP water, the groundwater may be extracted at any location within the AMA where the recharge occurred (if the facility is located in an AMA), and can be recovered at any point in time. SRP water must be withdrawn at the same location where it was recharged, and within one month from the time it is recharged. Although the recovered water is pumped from the ground, it technically is not considered groundwater and does not count against a utility's permitted groundwater withdrawal amount by ADWR.

2. Groundwater Supplies

Another solution to increasing water supplies is to drill and equip new groundwater wells. It also may be possible through certain measures to increase the production capacity of existing wells. If the well is located within an AMA, the owner would need to possess the necessary water rights or withdrawal permits from ADWR to drill a new well. Outside an AMA, no water rights or permits are needed and the owner must simply register its well with ADWR (an exception to this is for wells located within the younger alluvium along the Colorado River, where surface water rights are required).

Many utilities in Arizona utilize groundwater wells for domestic use. Because the rate of natural groundwater recharge is typically insufficient during droughts to keep pace with historic or even drought induced increases in withdrawals, it is common for static groundwater levels to fall several feet or even tens of feet over a period of years, especially in areas where overall groundwater use is high. It is important to test well pumps on occasion, approximately every six months, especially during drought conditions. As a minimum, the pump test should include determining the static water level, the pumping water level, and the pump discharge flow rate.

Water production from wells can over time decline for a number of reasons. Typically these include:

- Wearing of the pump mechanism, causing significant losses in pumping efficiencies;
- Plugging of the well casing perforations;
- Regional water level decline, resulting in a lower static water level.

In addition to adding additional wells to a distribution system, there are maintenance activities that can increase or restore water production in existing wells, such as:

- Installing a different pump impeller/pump motor combination to better match current pumping water levels;
- Mechanically or chemically cleaning the inside of well casings and screens to remove deposits that may be partially blocking slot openings;
- Chemically cleaning well gravel packs to remove deposits and/or biofilms that may be reducing the permeability of the material;
- Mechanically increasing the number well casing slots to increase water production;
- Deepening existing wells in an effort to reach new water sources.

Before any of the down-hole activities described above are undertaken, the well should be televised to check and verify the condition of the well including its alignment, well casing condition, casing deposit buildup, etc.

3. Upgrading of Existing Infrastructure

Many times, a drought situation may be made worse when the necessary facilities are not in place, or when existing facilities are inadequate, to produce enough water or deliver enough water to areas of need. It may not necessarily always be a supply problem, but rather a delivery problem. The necessary water sources might be available and adequate capacity might exist in the production facilities, but a transmission pipeline or pump station might be undersized to deliver the required amounts of water to a particular area. Alternatively, the delivery system might have adequate capacity, but the treatment plants or other facilities undersized to produce enough water to meet demands. Before new wells are drilled or other new water sources evaluated, a utility should evaluate the ability and capacities of its existing facilities to produce the required amounts of water and deliver it to where it is needed. Treatment plants could be expanded, new transmission and distribution pipelines installed, pump stations modified, and steps taken to increase the production of existing wells (as discussed in the preceding section).

4. Excess Stream Runoff

Another potential water source that a utility may take advantage of is to capture and store excess stream runoff that occurs during the spring snow melt. This runoff could be stored in detention basins

for use by a water treatment facility, or perhaps more beneficially, diverted into recharge basins for use in a groundwater recharge program. Of course, the utility would need to posses the appropriate surface water rights in order to accomplish this.

5. Water Purchase Agreements

Many municipalities and water utilities in Arizona obtain at least a portion of their water supply from wholesale water providers such as SRP or CAWCD. This water is typically raw water, which in turn must be treated at the utility's own potable water treatment facility. Another option to broaden a utility's water supply portfolio, or to firm up its available water supply, is to enter into new agreements with these providers, or to modify and increase existing agreements. A utility may also be able to purchase additional water from a nearby municipality or other water agency. The water purchase agreements could be for a guaranteed quantity and/or flow rate and the water added to the utility's base assured supply, or the agreement could be for back-up or emergency purposes only and water taken only when needed by the utility and/or available from the provider. The length of these agreements could be short-term or long-term, depending on the utility's need.

6. Water Hauling

In a serious drought situation where water supplies are simply not available, or in an emergency situation brought about by a major pipeline, canal, or infrastructure failure or contamination of a local water source, water hauling could be implemented as a temporary solution to deliver water to critical areas of need. Water hauling is literally the hauling of water to areas of need for distribution to impacted customers. This solution would obviously be limited to very localized areas and likely only implemented as a last resort measure. The water could be bottled water or even water hauled in tanker trucks, and would only be intended for consumption by humans and animals.

7. Temporary Pumping

Another "last resort" type of alternative to supply water to a particular area of need is by temporary pumping. Similar to bypass pumping commonly used in sanitary sewer maintenance and rehabilitation work, temporary pumping would involve installing temporary pumps and piping, often laid out directly on the ground surface, to deliver water to critical areas of need. There are of course practical limits to this alternative brought about by distance, equipment and pipe availability, and the proximity of source to destination, but this could be a very effective temporary solution to severe water shortage problems on a very localized level.

8. Alternative Water Supplies

Most Arizona communities have already fully developed their available high-quality water sources. However, there may be alternative water sources, such as effluent from wastewater treatment facilities, brackish groundwater, and lower quality surface water sources that possibly could be utilized by a utility to supplement its existing water supplies. These potential alternative water sources are described briefly below.

a. Reclaimed Water

Many communities in Arizona have already developed a reclaimed water program to utilize effluent from wastewater treatment facilities for irrigation of parks, golf courses, and

neighborhood common areas, for use in filling small municipal lakes, or in groundwater recharge programs. The Town of Gilbert is a good example of such a community. A reclaimed water system requires the construction of a second water distribution system, and therefore could be a very capital-intensive option to implement, depending on its scale. But it could also be a very effective means to significantly reduce potable water demands and conserve existing water sources.

Demands for reclaimed water are very seasonal, with the majority of use occurring during the summer months when irrigation demands are at their peak. Fortunately, this is also when the effects of drought are hardest felt, and when the use of reclaimed water can make the biggest impact. During the winter months when irrigation demands are low, reclaimed water provides an excellent water source for groundwater recharge projects. Typically, a utility can receive recharge credits from ADWR for reclaimed water recharged into the ground, just the same as for other water sources. An equivalent amount of groundwater can then be extracted through recovery or other wells, and that quantity will not counted against the utility's permitted withdrawal amounts by ADWR.

b. Brackish Water

Water sources high in TDS and salts generally have been avoided as potable water sources. However, as existing higher quality water sources are depleted, the use of brackish water is becoming more popular. Brackish water generally can be treated to acceptable drinking water standards through reverse osmosis or other membrane treatment systems. Many existing irrigation wells pump water that is brackish. As agricultural lands are gradually retired and developed, there may be an opportunity for utilities to purchase irrigation wells and incorporate them into their distribution system. These wells can be converted to municipal wells with relatively minor modifications, the water treated appropriately, and then discharged into an existing potable water distribution system.

DEMAND SIDE STRATEGIES

In addition to supply side options, it is equally important to consider demand side options in order to maximize the effectiveness of a drought mitigation plan. Demand side strategies that could be implemented include making distribution system improvements, water conservation, water restrictions, irrigation guidelines and/or requirements, and non-traditional activities such as rainwater harvesting or gray water collection and reuse.

Distribution system improvements could include the upgrading of existing infrastructure to increase capacities, implementing a leak detection and repair program, lining or piping of canals, repair of damaged canal linings, and other similar alternatives to control water losses. Water conservation includes both indoor and outdoor measures, such as installation of low-flow plumbing fixtures and water-efficient landscaping, respectively. Public education programs could also be employed to distribute water conservation tips, demonstration gardens constructed to display efficient landscaping techniques, etc. Irrigation guidelines and/or requirements could include restricting lawn watering between certain hours (e.g., 10 am to 7 pm) to minimize evaporation losses, odd-even watering days, etc. Conservation inducing water rates or rate structures would penalize customers for excessive water use and encourage conservation.

Although many of these alternatives are not necessarily short-term solutions to drought, they would be tremendously helpful during drought periods by lowering demands and extending the adequacy of existing water supplies. Water restrictions are more of a short or immediate-term response to drought and, with proper planning, would only be necessary under the most severe conditions.

1. Distribution System Improvements

a. Leak Detection and Repair

A typical water distribution system looses about 10 percent of its water supply to leakage and other unaccounted for losses. In some older system, or those in disrepair, this loss may be as high as 30 percent or more. This obviously creates an enormous opportunity for a utility to conserve water and extend the adequacy of existing supplies by minimizing these losses. Technologies now exist that can aid a utility in locating significant leaks in pipelines, such as ultra sensitive listening devices. Once these leaks are identified and pinpointed, they can be repaired and the water saved.

Most utilities have only a reactionary approach to leak repair. That is, they only react to and repair leaks on an emergency type basis - when they become visible or when other problems surface directly attributable to leaks (i.e., ground subsidence, etc). Many minor leaks, however, may be active for long periods of time, perhaps years, before they become visible or create problems and are identified and repaired. There are a number of utilities that have developed formal leak detection and repair programs. These programs are aimed at systematically evaluating all major pipelines within a utility's distribution system and identifying and repairing leaks.

b. Metering

Along with leak detection and repair, metering is another measure that a utility can implement to help control or minimize unaccounted for water and other losses. Metering by itself may not immediately reduce water demands like repairing large leaks. However, when combined with appropriate pricing structures, it does give a utility the tools it needs to provide customers with an incentive to conserve water. Also, the more information a utility has on where its water is being utilized, the better it can manage and control its water resources.

c. Canal Lining or Piping/Lining Repair

Another method to potentially conserve large quantities of water is to install linings on canals to minimize seepage losses, or to repair or replace existing linings that have deteriorated. Most canals that convey water for potable supplies are lined, but the condition of these linings deteriorates over time. This ultimately leads to water loss due to seepage through the damaged areas, or potentially even failure of the canal. The condition of these linings should be inspected regularly and repaired as necessary to control leakage.

2. Water Conservation:

Most large water agencies and municipalities in Arizona have implemented some sort of a water conservation program. ADWR requires that water providers within AMAs achieve certain water conservation goals aimed at reducing average daily per capita consumption. These goals become

stricter with each successive Management Period. ADWR is also completing its first Water Conservation Plan for the State of Arizona.

Water conservation can be separated into indoor and outdoor conservation. It can furthermore be categorized into voluntary measures and mandatory water use reductions. Mandatory water use reductions are usually limited to outdoor water use, and typically involve irrigation restrictions of varying degrees.

Numerous articles have been written on water conservation and a virtually unlimited amount of information and resources are available on the subject. It is not the intent of this paper to address this subject in great detail, but only to highlight some of the more effective means of conserving water.

a. Public Education:

A public education program is generally considered essential for a successful water conservation program. Although geared more towards long-term results as opposed to short-term gains, the purpose of a public education program is to re-educate older water consumers who may not practice water conservation techniques, and to educate younger water consumers on efficient water use techniques and practices. Typical public education methods include distribution of water conservation tips and information in water bills, television and radio advertisements, school presentations, and construction of demonstration gardens to showcase water-efficient landscaping techniques.

b. Indoor Conservation:

Perhaps the most effective indoor water conservation technique is the installation of low-flow plumbing fixtures and appliances. Low flow showerheads and toilets, aerators on water faucets, water conserving dishwashers, and front loading washing machines are examples of plumbing fixtures and appliances that are available to reduce indoor water use. Some municipalities or jurisdictions also prohibit, or at least discourage, the use of garbage disposals in new construction. Many communities in Arizona offer incentives or rebates for the installation of low flow plumbing fixtures in homes.

Another effective method to reduce indoor water use is to install hot water recirculation pumps. In most households, large amounts of water are usually wasted down a drain while waiting for it to heat up. Recirculation pumps are typically installed below sinks, or near tubs and showers, and recycle water from the sink back to the water heater until it reaches a certain temperature. As another option, instantaneous hot water heaters may also be utilized in lieu of a traditional hot water heater to provide instant hot water on demand. Some communities in Arizona have implemented programs to encourage the use of these types of facilities. For example, the City of Goodyear requires the installation of electrical outlets underneath all sinks in new construction, and also offers rebates for the installation of recirculation pumps.

c. Outdoor Conservation

In some parts of Arizona, outdoor water use accounts for over two-thirds of residential water use. Accordingly, outdoor conservation programs may provide the largest opportunity to reduce water demands. Most outdoor conservation plans focus on reducing the amount of

water used or required for irrigation. Common measures to accomplish this include water efficient landscaping and the implementation of irrigation guidelines or requirements. These measures are discussed briefly below.

1) Water-Efficient Landscaping

Water-efficient landscaping, or Xeriscaping, can be defined as an attractive, sustainable landscape based on sound horticultural practices that conserves water. Xeriscaping is a package of seven common-sense steps for making a landscape more water-efficient:

- Planning and Design. Creating a water-efficient landscape begins with a well-thought-out landscape design.
- Soil Analysis will determine whether soil improvement is needed for better water absorption and improved water-holding capacity.
- Appropriate Plant Selection keeps the landscape more in tune with the natural environment. Both native and exotic plants make up the huge variety of plants available for Xeriscape landscaping. A list of low water use/drought tolerant plants appropriate for use in Xeriscaping is available for each AMA on ADWR's website.
- Practical Turf Areas. Using turf areas effectively and not extensively. Avoiding impractical turf use, such as long, narrow areas. The reduction or elimination of high-water-use turf areas, and locating them separately so that they may be watered more efficiently, can result in significant reductions in water use.
- Efficient Irrigation Systems, such as sprinkler or drip irrigation.
- Use of Mulches in flower and shrub beds to prevent water loss from the soil through evaporation and to increase water penetration during irrigations.
- Appropriate Maintenance preserves the beauty of the Xeriscape landscape plus saves water. Pruning, weeding, proper fertilization, pest control and irrigation system adjustments all conserve water.

2) Irrigation Requirements/Water Restrictions

The implementation of programs or the passing of landscape ordinances encouraging or requiring water efficient landscaping are effective in reducing a utility's overall water demands over the long-term. As such, these measures help to reduce a utility's vulnerability to drought by extending the adequacy of existing water supplies and infrastructure. This section will discuss outdoor conservation measures that can be implemented to produce almost immediate results. These are irrigation requirements or water restrictions.

Typical irrigation requirements or restrictions that could be employed are restricting lawn watering between certain hours of the day to minimize evaporation losses, odd-even watering days, or only allowing watering on certain days of the week. In the odd-even scenario, certain customers might be allowed to water only on odd-numbered days, and others only on even-numbered days. These restrictions could be voluntary or mandatory, and could increase in severity as drought conditions increase in severity. As would be expected, mandatory restrictions are more effective at

reducing water use than voluntary restrictions. The effectiveness of water restrictions may be illustrated by the following example.

During the summer of 2002, much of Colorado was in the midst of a severe prolonged drought and many communities in the Denver metropolitan area implemented water restrictions. Some of these restrictions were voluntary and some mandatory, and all varied in severity. In the most lenient case, lawn watering was restricted on a voluntary basis to once every three days. In the most severe case, restrictions were mandatory and lawn watering limited to only once per week. In all cases, the utilities experienced reductions in water use compared to their expected water use given the existing meteorological conditions. These reductions ranged from between 4 to 12 percent for the voluntary restrictions, and between 18 to 56 percent for the mandatory restrictions. As evidenced by this example, water restrictions can be a very effective tool for reducing water demands.

3. Gray Water

Gray water is defined by ADEQ as "wastewater, collected separately from sewage flows, that originates from clothes washers, bathtubs, showers, or sinks, but not from a kitchen sink, dishwasher, or toilet." As a means to reduce water demands, a utility could encourage its customers to install facilities to collect and use gray water at individual homes. A permit from ADEQ is not required to use gray water, but users are expected to follow the guidelines for a Reclaimed Water Type 1 General Permit. Allowable uses for gray water include lawn and landscape irrigation, household gardening, and composting. Gray water may only be distributed with a flood or drip irrigation system. Spray irrigation is not permitted. Additional information on this topic may be found on ADWR's website.

4. Rainwater Harvesting

Rainwater harvesting was once a very accepted and widely practiced method to obtain water in many areas of this and other countries, but with the advent of large, community water treatment and distribution systems, its use has dwindled. Rainwater harvesting is accomplished by installing facilities to collect and store rainwater from a variety of surfaces. Depending on whether the rainwater is to be used for potable and/or non-potable purposes, these may include roofs, driveways, parking lots, and other impervious or semi-impervious surfaces. Following catchment, the rainwater is diverted into storage basins or tanks, where it is stored and used as needed. It can also be directed toward a well or pit designed to recharge an existing well or the local aquifer.

Besides providing water for drinking or other purposes, advantages of rainwater harvesting include: 1) reductions in storm water run-off and associated erosion, pollution and traffic problems, and 2) reduction in standing water and mosquito breeding habitats, especially during the monsoon season.

Rainwater harvesting has residential, commercial and large industrial applications. (http://www.fordvehicles.com/environmental/greenerplant/index.asp?bhcp=1#copy1)

Rainwater is generally of high quality, is naturally soft, and has not been influenced by contact with soil and rocks where it would dissolve salts and minerals, or by chlorine, fluoride and high sodium content such as occurs with groundwater that has been treated for public use. Rainwater provides an excellent source of water for the irrigation of lawns, gardens, and landscaping, and with minimum treatment, can be used for domestic uses.

In some developed countries, including Australia, rainwater harvesting is widely encouraged for both domestic and non-potable use. Other countries, such as Singapore and Bermuda require by law that all new construction incorporate rainwater harvesting systems. The City of Tucson requires the capture and on-site detention of rainwater at all public buildings, commercial developments, subdivisions, and public rights-of-way for supplemental irrigation purposes. An excellent publication on rainwater harvesting is available from the City of Tucson entitled "Water Harvesting Guidance Manual." The Texas Water Development Board also publishes a manual entitled "Texas Guide to Rainwater Harvesting". More information on this can be found at: http://www.twdb.state.tx.us/assistance/conservation/Alternative_technologies/Rainwater_Harvesting/Rain.asp or http://www.dot.co.pima.az.us/flood/wh/info.html or http://www.arcsa-usa.org.

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M&I Attachment 5

Developing and Implementing a Municipal Water Provider Drought Plan

INTRODUCTION

Having a drought response plan has become increasingly important for municipal water providers throughout the state of Arizona. This section provides a brief overview of the components of a drought plan, and discusses the steps that a utility might take in developing and implementing (if necessary) a drought response plan for their water service area.

Utilities are increasingly discovering the need to develop drought response plans in preparation for the unusually dry conditions that we are currently experiencing in Arizona. Every drought response plan has certain key elements that are universal.

A drought response plan typically defines increasingly severe levels of drought based upon the amount of water demand reduction required to meet available supplies. These levels of drought are triggered by various reductions in available supplies. The triggers can vary depending upon the type and reliability of available water supplies.

A drought response plan should also contain descriptions of the measures proposed to reduce water demand at each drought level. These measures typically move from less stringent to more stringent and from voluntary to mandatory. The plan should also describe the mechanisms that will be used to enforce compliance with the mandatory water use reduction measures.

SYSTEM AND SUPPLY INVENTORY

In order to determine the impact that a drought will have on a municipal water system, a utility first needs to inventory the water supplies available, and the infrastructure to deliver them to customers. Water supplies should be reviewed from a "worst case" scenario. For surface water supplies, the history of flows should be examined, paying particular attention to those years when the lowest deliveries were reported. This is a good place to start for planning. However, this may not cover all bases, as extraordinarily dry conditions may lead to unforeseen delivery reductions, as happened in 2003 when Salt River Project reduced it's water deliveries by one-third to its shareholders in the metro Phoenix area.

When looking at the "worst case" well supply, consider a couple of things. First of all, consider what would happen and what could be done if all groundwater wells became unreliable due to declining water levels. Then consider what would happen if only a portion of the well supply was lost. The amount of system storage available must also be considered when planning for supply shortage conditions. An emergency response plan may be a valuable tool in assessing the vulnerability of water providers.

As the availability of water supplies is assessed, the water provider should also look at unique local conditions that may affect the ability to obtain reliable quantities of water. The Endangered Species Act (ESA) is increasingly affecting surface streams throughout the state. As endangered species

become more prevalent in a stream stretch, their needs often compete with the needs of the human water users utilizing the same supply. In a time of shortage, it may be possible that a court could decide that the endangered species' needs take precedence, requiring a water provider to leave water in a stream that could otherwise by used for meeting system demands.

Another limitation on supply availability in Arizona is the ban on transferring groundwater supplies between groundwater basins except in certain limited cases. This ban is an outgrowth of Phoenix area cities purchase of "water farms" in the 1980s, and was designed to ensure that groundwater supplies were left with the land. If a water provider is on the edge of a basin boundary, they may not be able to simply construct a new well in another basin and transport the additional water to their system. Groundwater basin maps are available at the Arizona Department of Water Resources office in Phoenix.

The next step in developing a drought plan is to compare available "worst case" supplies to expected demands. This will help approximate how much water demand would need to be reduced in the event of drought. In addition to looking at average day demand, be sure to look at peak day and peak hour demand. It may be that a provider can supply average demand even without all of its wells if they have sufficient system storage, but that peak day and peak hour demands may drain storage tanks faster than their wells can refill them.

DROUGHT TRIGGERS

As the drought plan is developed, it will need to define trigger points to implement various levels of drought mitigation measures. These triggers will be very specific to the water supply system. Factors influencing drought triggers typically include: types of supplies, amount and location of water storage, distribution system capacities, and interconnections with other systems.

Very specific criteria exist for a private water companies who apply for a Curtailment Tariff from the Arizona Corporation Commission (ACC). The ACC defines specific triggers and specific measures associated with each trigger. Their triggers are based upon the levels of storage capacity and/or amount of well capacity available. As storage capacity or well capacity decreases, the measures become more severe. The ACC's triggers and measures are more fully described in Attachment 3.

If a system relies on heavily on surface supplies, there are several factors to consider when developing trigger points. The first is rainfall. If rainfall levels are low, it is reasonable to expect that surface supplies will be lower at some point in the future. Rainfall is more of a factor if there is no reservoir storage available for the system's surface water supply.

The amount of streamflow is also an important factor to consider. This is again more important if a utility does not have reservoir storage available to carry itself over during short-term decreases in stream flow. The final factor to consider is the amount of reservoir storage remaining in surface supply reservoirs. Triggers based upon reservoir storage are typically set by the entity operating the reservoir, and are based both upon existing levels of reservoir storage and future expected runoff.

Groundwater supply triggers are much harder to define, because they are affected by much more than surface water drought. When looking at developing a drought trigger for groundwater supply usage, a utility will want to consider water level declines and well capacity reductions. At some point, as water levels decline, a utility will most likely determine that it is no longer economically feasible to

deepen a well to follow the water, and therefore, it could run into a supply shortage. However, this may be due to many factors other than drought.

After considering all the above factors, the utility is ready to develop its "worst case" scenario. This is defined as the absolutely worst possible thing that a drought could do to the utility's water supply. It becomes the most severe stage or level of drought, with the most severe and mandatory demand reduction measures. Drought plans typically contain four stages, so once the worst case is defined, the other, less severe levels can be defined, until a normal, non-drought level is attained. These levels define the points at which the various drought response measures will be implemented.

DEMAND REDUCTION MEASURES

Once water use reductions to meet available supplies have been determined, a utility will need to define appropriate ways to reduce those water demands. Measures will differ from service area to service area, depending on the types of water use that are most common.

Some of the more common examples of water demand reduction measures are included in Attachment 1, which summarizes the components of a drought plan. Typical actions taken include reducing the amount of landscape irrigation by both residential and non-residential users, and offering water use audits to customers.

Drought-related conservation measures must be easily enforceable. They should be things that a utility can keep track of without too much trouble. For example, if a utility limits or prohibits landscape watering, it should be done on days of the week when there are employees available to inspect for compliance. Don't prohibit watering on the weekends, when a utility may have to pay overtime.

Water utilities should also set a good example. Make sure the utility's water delivery system is in good repair before asking customers to cut water use. The system should be inspected for leaks and those found should be promptly repaired. Also, the utilities' own landscaping should be watered efficiently such that there is no perception of waste. Make sure all water department buildings are landscaped with low water use plants, and office plumbing fixtures utilize low flow devices. This will go a long way toward making any drought-related conservation measures more palatable to customers.

DROUGHT PLAN ENFORCEMENT

One of the greatest challenges of developing a drought plan is deciding upon how best to enforce it without stepping on too many toes. This component of the drought plan needs plenty of public comment during the plan development process.

If the utility is also a municipality, drought plan measures cannot be enforced without an ordinance. This ordinance gives the Council or City Manager or other designee the ability to declare drought, and the ability to enforce the drought plan. The ordinance will also describe the enforcement mechanisms. Typical mechanisms used for enforcement include citations, fines, water flow curtailment, or even cut off of water service for the most egregious offenders. The ordinance should, however, allow exceptions to the water use reduction measures for health and safety reasons, upon approval by the City Manager or other authority.

Levels of drought enforcement should gradually increase depending upon the severity of the offense, and the number of times that it has been repeated. For example, the first time a customer waters on a non-authorized day, they might get a warning. The second time, they might get a ticket and pay a fine. The third time, they might pay a bigger fine and have their water use curtailed. The fourth time, they might have their water turned off.

A private water company is required to apply to the ACC for a Curtailment Tariff and file a Curtailment Plan in order to enforce drought-related demand reduction measures. The ACC requires very specific measures at the different drought stages, gradually increasing in severity as drought worsens.

Deciding which personnel will enforce the drought ordinance or curtailment plan is difficult, especially in these financially strapped times, when everyone is doing more with less. It is usually recommended to utilize code enforcement or law enforcement personnel, as they have the specific training in documentation of violations, which may be required in the case of a repeat offender who is going to court. Should other types of personnel be utilized, it is important that they have training in documenting cases and dealing with the public.

The final thing to consider when developing an enforcement strategy for a drought plan is the cost of enforcement. How will the utility pay for the "lawn watering police"? Many utilities implement a drought surcharge or curtailment tariff to offset the costs of regular inspections and enforcement proceedings. As a drought plan is developed, the utility will need to work closely with the agencies and others who will be enforcing it to keep a handle on both costs and staff requirements. This will ensure that if it becomes necessary to implement such a plan, unexpected surprises are minimized.

PUBLIC INVOLVEMENT

Public information and education programs are an important component of the plan development process. The utility should identify the groups of people that will be affected by the drought plan and develop a strategy for communicating with and involving each of them. One good way to get started with this is to designate one person within your organization as the "drought liaison" – the person that everyone goes to for drought information. This could be a public information officer or a water conservation person or could simply be someone from the utility's office staff.

The group that will be most directly affected by the utility's drought plan is their customers. Implementing the drought plan will affect both their homes and businesses, so they need to be involved in plan development from a very early stage. Keep them informed and enlist their help in developing plans to save water and respond to drought. Often they will come up with ideas that the utility staff have not considered.

The utility's board of directors or City Council must also be kept up to date. They may not be interested in the details as the plan is being developed, but will certainly want to have input into the finished product. They also will want to be aware of what is being proposed so as to address potential political ramifications.

It may be helpful to convene a small working group of concerned citizens and community members to help with plan development. They can serve as a sounding board, and as a resource for new programs and concepts. If they buy into the plan as it is being developed, they can also serve as strong advocates for the need for the plan within the community once the plan is completed.

Once a draft of the plan is completed, public meetings and workshops should be held to explain the plan within the community. Take advantage of opportunities to speak to community groups and enlist their support. Talking to school groups has also proved to be effective in getting the message across. As you receive and incorporate public input, the utility's governing board should be kept up to date.

As the impacts of the plan on the community are communicated, the need for the plan, and what will happen if a drought plan is not put in place should be explained. This helps customers understand that this is not something the utility is doing to complicate their lives.

In order for the drought plan to be effectively implemented, it should be publicly adopted by the utility's governing board. Ample public notice of the meeting should be provided in order to give customers ample opportunity to comment and participate, though ideally all concerns should have been addressed before presenting the plan to them for approval. Official approval and public notification will make the plan more easily enforceable, as it will have the weight of official action.

IMPLEMENTING A DROUGHT PLAN

Implementing a drought plan is something any water provider hopes that they never have to do. In order for the plan to be effective in reducing water use, there are several things to keep in mind.

1. Have a communications plan.

When a utility's drought plan is being prepared, it is hoped that either it will never need to be deployed or that the utility is in the middle of a drought the plan needs to be quickly implemented. Either way, the utility will need a communications strategy when the drought plan is implemented.

The communications strategy looks a lot like the strategy the utility used when it developed the plan in the first place. First, the utility should name a "drought liaison" to serve as the point of contact for drought related questions from your customers or from other employees.

There are several audiences that the utility will want to reach with information about the drought plan and what exactly is underway. The utility's employees need to have a clear understanding of what's in the plan, and what their role is in enforcing it. For example, are they expected to write tickets? The best mechanism for this is to hold an employee meeting just before the drought plan is formally implemented. Introduce the drought liaison (if people don't know him/her already), and refer future questions to that person. Your governing body should also be briefed in a similar fashion.

As the drought plan is implemented, the most important audience to reach is the utility's water customers. There are many ways to publicize that a drought has been declared. Customers also must be told what they are expected to do. Experience has been that most people are willing to conserve if they perceive there is a real need to do so.

Make sure notice of the drought is adequately published, and that the name and contact information for the drought liaison appears prominently in any news release or media advisory. Use the print, radio, and television media if they are available and within the utility's budget. Media are always willing to carry an important story like upcoming drought restrictions.

Prepare fact sheets and talking points to use in communications with the media and with customers. Choose two or three points to consistently make, such as "we're ready" and fill in fact sheets around them. Talk about specific actions the utility is taking to prepare for the drought, impacts that the drought could have on the community if the drought plan isn't followed, and actions the customers are expected to take. Include these fact sheets as inserts in utility bills, if there is room. This is one way to be sure that every customer receives one.

Finally, a speaker's bureau of employees can be very useful in getting the word out. Make them available to speak at civic groups and service clubs. Depending on the audience, using line employees can be very effective in building relationships with the community, because they are perceived as "average Joes" and thus can have higher credibility.

2. Give your customers help & enforce the plan evenhandedly.

Implementing a drought plan will likely mean asking customers to take certain actions to conserve water. Give them as much help as possible. Provide staff assistance and water use audits if at all possible. Oftentimes, customers will want to save water, but will not know which actions to take. Provide conservation information and literature at the utility's business offices. Additional resources are also available via the internet. The "Water Use It Wisely" website (www.wateruseitwisely.com) has many conservation tips, and links to other conservation sites.

Consistent enforcement is critical as the mandatory stages of the drought plan are implemented. All provisions of the drought plan must be consistently equally enforced among customers; there can be no special treatment. Each application for a variance from the plan requirements must be scrutinized carefully, and consistent criteria must be used to evaluate each one. Obtain and complete documentation of the reasons for granting or denying the request in the event the decision is later challenged.

There are two ways to enforce the requirements of a drought management. One is proactive; the other is reactive. Proactive enforcement involves enforcement by water provider staff (such as meter readers) and/or local law enforcement personnel. This can be costly, in time spent getting staff properly trained, and in time spent away from other duties. However, it has the benefit of being much more likely to be perceived as evenhanded and fair.

Reactive enforcement relies upon citizens and customers to report violations, with follow up by the water provider. This has the benefit of being less costly than the alternative of using in house staff, but does have the potential for uneven and unfair enforcement, as neighbors may use the excuse of drought management to settle old grudges. Therefore, choose to use reactive enforcement only if you have no other alternatives.

CONCLUSIONS

A water supply drought is something no municipal water provider wants to implement. Utilities don't want to admit they might not be able to deliver water or maintain water pressure. However, if a utility plans their drought response in advance and keeps the public informed about what's going on, the negative impacts of declaring a drought should be minimal.

REFERENCES

American Water Works Association www.awwa.org

- Handbook: Drought Management Planning
- Small systems forum
- www.waterwiser.com

Arizona Water Pollution Control Association (www.awpca.org) - Circuit riders program conservation information.

Water Use It Wisely (www.wateruseitwisely.com)

Attachment 1

Model Drought Demand Management Plan*

Drought Stage	**Public Agency Actions**	**Requested Consumer Action**	**Penalties for Wasting Water/Exceeding Allocation (progressive)**
Phase 1 – Watch 5-10 percent shortage (Voluntary reductions)	-Initiate public information campaign -Request voluntary conservation -Begin census data collection	**All Customers** -Implement voluntary water use reductions	1. Educational letter or visit
Phase 2 – Warning 10-20 percent shortage (Voluntary or mandatory reductions)	-Mandate voluntary conservation actions for municipal agencies, parks, school districts, etc. -Reduce water use for street sweeping, main flushing, landscaping -Initiate conservation rate changes or surcharge	**All Customers** -Adhere to nonessential use ordinances **Commercial Customers** -Voluntary implement contingency action plan -Car washes install recycling equipment -Evaporative cooling systems set minimum temperatures to 75º F	1. Educational letter or visit 2. Educational visit and warning 3. Citation or fine 4. Installation of flow restrictor 5. Shutoff and reconnection fee 6. Excess use fee
Phase 3 – Emergency 20-35 percent shortage (Mandatory reductions)	-Institute rationing through fixed allotment based on census data -Require low-flow showerheads and ULF toilets -Implement rate changes or surcharge -Use reclaimed water for street cleaning, landscaping	**All Customers** -Adhere to nonessential use ordinances -Manage water consumption -Read water meter weekly to monitor usage -Require covers on all public pools **Commercial Customers** -Implement contingency plan	1. Educational letter or visit 2. Warning visit 3. Citation and fine 4. Excess use charge 5. Flow restrictor for continued or excessive use 6. Shutoff and reconnect fee
Phase 4 – Critical 35-50 percent shortage (mandatory reductions)	-Intensify emergency phase actions -Monitor meter use weekly -Allocate water per capita or per service -No potable water use on landscaping -Prohibit all public water uses not required for health or safety	**All Customers** -Same as phase 3 **Commercial Customers** -Implement water use contingency plans -Close public pools, car washes -Close schools and offices -Shut down industrial operations	1. Warning visit 2. Citation and fine 3. Excess use charge 4. Flow restrictor for continued or excessive use 5. Shutoff and reconnect fee

Note: Consult with legal staff of your organization when developing regulatory components of the plan; the writing of a citation needs to have the same legal backup as any other ticket in order to be enforceable.

* From AWWA Manual: *Drought Management Planning*, 2002 (modified)

Appendix XI
WHITE PAPER – TRIBAL IMPACTS

Inter Tribal Council of Arizona, Inc.

In Support of the National Congress of American Indians Testimony on Western Drought
Drought in Arizona and Its Effects on Tribal Lands
March 5, 2004

Background

The Inter Tribal Council of Arizona comprised of 19 tribal governments addresses many issues, concerns, and matters that affect tribal communities. Facing water shortages as a result of the drought is a critical issue for tribes. Tribes significantly depend on water as a major source of drinking water, domestic uses, agriculture, recreation, and other uses. Through discussions with tribal representatives, ITCA has broad knowledge of the affects the drought has had on tribal communities. The following is an outline of some of the effects tribal representatives have conveyed.

Effects of Drought

1. Shortage of potable water for human consumption.
2. Shortage of forage/vegetation for animals resulting in reduction of herd animals.
3. Shortage of ponds and tanks not filled by rainwater resulting in a decrease in wildlife, which is affecting hunting and fishing revenues.
4. Irrigation for farming is drawing down groundwater.
5. Fire danger due to dry undergrowth.
6. Increase in groundwater use, which is depleting aquifers.
7. Decrease in tourism.
8. Mental and physical stress, especially on tribal farmers and ranchers.
9. Health effects due to increase in dust and airborne agents.
10. Groundwater subsidence due to groundwater use and drilling of new wells to offset the shortage of water that is caused by the drought.
11. Loss of native plant species used for cultural or traditional uses.
12. Diverting funds from needed infrastructure and other programs to assist with drought management.
13. Destruction of thousands of acres of timber by bark beetles causing severe economic damage and increasing the fire hazard.

Methods in Use to Offset the Effects of Drought

1. Hauling of potable water or buying bottled water.
2. Hauling of water for livestock to fill tanks.
3. Decrease herd size.
4. Limit hunting and fishing due to fire concerns.
5. Drilling additional wells to tap groundwater supplies.
6. Increase of personnel monitoring the health of forests, grasslands, and transitional zones.

Specific Examples

1. White Mountain Apache Tribe directly affected by the wildfires in the White Mountains. The fires significantly impacted their economic viability since forestry is a major source of revenue for the tribe.
2. Tohono O'odham Nation hauling water using five tanker trucks for livestock, supplemental feed (hay) for livestock, herd reduction, using groundwater wells to water wildlife.
3. Navajo Nation hauling water for livestock, major supplemental livestock feeding and reducing herds.

For additional information contact: Inter Tribal Council of Arizona, Inc. 602-258-4822

Appendix XII
WHITE PAPER – OTHER CROSS-SECTOR IMPACTS

Governor's Drought Task Force -
Electric Power Provider Drought Issues
August 23, 2004

1. Introduction

   Drought can affect Arizona electrical energy supplies and demands in several ways. They include reduced hydrogeneration, reduced thermal plant generation, increased thermal plant cooling water demand, increased consumer energy demand, reduced electric system reliability and increased power costs.

2. Impacts and Vulnerabilities

   Colorado River Hydrogeneration – Reduced reservoir releases due to water restrictions reduce power production. Falling lake water levels during droughts further reduce the amount of power that can be produced. If water levels fall far enough, the turbines will need to be either modified or shut down completely.

   SRP Hydrogeneration – SRP owned hydrogeneration makes up only about 5% of SRP's total power generation portfolio. SRP has two types of hydrogeneration, Run of River and Pump-Storage. Run of River generation, like that on the Colorado River, is affected by reservoir releases and lake levels. Pump-Storage generation occurs at two SRP dams and is independent of downstream water demands. However, Pump-Storage would be affected if there were insufficient water to keep the reservoirs at their required operating levels.

   Thermal Power Plants – Arizona thermal power plants rely on water for their cooling towers. However, water supplies could be limited during droughts and could affect power production.

   Increased Consumer Demands – A variety of drought related conditions could result in short-term increases in electrical power demands. Conversely, there are other conditions that could lower electrical demands.

   Reduced Electric System Reliability – This can result from wildfires, prescribed burns and debris on electric insulators.

   Increased Power Costs – Could be caused from supply and demand based issues on both the wholesale and retail levels. For example, low reservoir levels limit the ability to produce low-cost hydroelectric power at the same time energy demands could be increasing for groundwater pumping and air conditioning systems.

3. Mitigation Options

   Response options include:

   - Purchasing power from merchant power plants with excess capacity. However, electric transmission capacity could be an issue.
   - Lowering lake water intake tubes at Navajo Generating Station to allow it to operate at lower Lake Powell water levels.
   - Delay the planned shutdown of the Mohave Generating Station. However, there are coal, water and air quality issues that would need to be addressed.

   Adaptation options include:

- Converting thermal power plant cooling towers to utilize air for cooling rather than water.

Impact of Drought on Public Health in Arizona

Arizona Department of Health Services (ADHS)

Key public health issues related to drought include water quality and quantity, mental health and stress, air pollution, zoonotic diseases, and nutrition and hygiene. In addition, fires associated with drought often result in severe episodes of air pollution. Biomass burning can cause acute respiratory disease and exacerbate chronic respiratory disease in children and adults.

Impacts of Drought

Zoonotic diseases: Drought may increase the occurrence of zoonotic diseases such as plague, hantavirus, and rabies. Human cases of these diseases are unpredictable under any environmental conditions. Drought may cause more animals to concentrate near available water sources increasing the likelihood of spreading disease, and may lead to urban encroachment among animals and increase human exposures.

Nutrition and hygiene: Food establishments and schools may experience insufficient quality or quantity of water supplies for food preparation and/or personal hygiene.

Air pollution: Drought may cause an increase in airborne particulates due to reduced precipitation and increased risk of wildfires. Exposure to smoke and dust may cause short-term health effects including eye, nose, throat, and lung irritation. Individuals with asthma, other lung conditions, or heart disease may be more vulnerable to the effects of dust and smoke.

Mental health and stress: The agricultural industry is the most affected by adverse health effects and stress attributed to drought. Impacts may include suicide, abuse, and increased rates of mental illness.

Mitigation Options

Surveillance: The ADHS monitors vector-borne diseases through surveillance for human disease. The agency coordinates animal surveillance for zoonoses and monitors the potential for transmission of infectious agents and recommends abatement and prevention measures.

Nutrition and hygiene: The ADHS provides guidance for food establishments and schools during a community water outage. The guidelines are located at **www.hs.state.az.us.phs.oeh/fses/index.htm**.

Air pollution: The Arizona Department of Environmental Quality ensures the safety and quality of the air in Arizona by monitoring and analyzing air quality data, and regulating sources of air pollution. The department issues air pollution advisories and warnings when pollution levels have reached a level at which people with respiratory or other health problems may experience adverse health impacts.

Mental Health & Stress: The ADHS Division of Behavioral Health Services (ADHS/DBHS) contracts with Regional Behavioral Health Authorities (RBHAs), to administer behavioral health services throughout the State. RBHAs contract with service providers to deliver behavioral health care services, including prevention programs, substance abuse programs, and general mental health disorders.

Governor's Drought Task Force -
Drought Related Water Quality Issues for Arizona
August 23, 2004

Introduction

Drought contributes to degradation of Arizona's water quality through primary (direct) and secondary (indirect) means, and the impacts affect the ability to use the water for drinking, urban industrial, agriculture, mining, habitat, power production, and recreation purposes.

Impacts and Vulnerabilities

Direct impacts include the concentration of pollutants, increased water temperature, less buffering capacity of pH, lower dissolved oxygen, and increased color and odor. Indirect impacts include those caused by fires, overgrazing, low water levels, and reduced riparian and aquatic vegetation. Increases in soil erosion and total organic and nutrient loads exacerbate and prolong the impacts.

a. Drinking Water – Increased pollutant concentrations (chemical and biological) increase the chemical and other operational costs associated with operating water treatment plants. Some treatment plants may not be able to respond to some pollutant loads. In general, the more prolonged the drought, the more susceptible groundwater is to deterioration of quality. Conservation contributes to water quality problems by increasing water age within distribution systems.
b. Sewage Treatment – The ability to discharge treated wastewater is negatively impacted by drought because less flow in receiving water means discharges will have greater impact.
c. Urban Industry & Mining – Many industries rely on a consistent water quality for their processing needs. Consistent concentrations of salts and mineral content are particularly important. Drought increases these concentrations, and the need of water providers to switch among available sources to meet demand leads to fluctuations in water quality.
d. Agriculture and Ranching – The concentration of salts and minerals combined with the pressure to conserve water leads to short term lower crop yields and long term soil problems. Livestock yields are lower, and incidence of disease increases as a result of less water availability. Increased salinity and metals content in soil, water, and vegetation cause gastrointestinal problems in livestock.
e. Habitat – Increases of dissolved solids, lower dissolved oxygen, less pH buffering capacity, and increases of toxic blue-green algae are detrimental to aquatic and terrestrial wildlife.
f. Power Production – Fish-kills and increased loadings of wood and suspended solids in reservoirs gum up and damage the intakes and mechanical equipment of hydrogenation facilities.
g. Recreation – Fish-kills and high concentrations of microbiological pollutants may contribute to reduced ability to enjoy publicly accessible water bodies.

Mitigation Options

h. Identify and control sources of pollution in watersheds.
i. Determine water quality impacts of instituting water system conservation, and develop operational strategies to mitigate them.
j. Install constructed wetlands in watersheds where necessary.
k. Obtain samples of source water and conduct bench top treatment tests to determine necessary treatment strategies.
l. Install runoff and erosion barriers.
m. Use groundwater to temporarily and occasionally "flush" concentrated pollutants through surface water systems.
n. Reduce stock loads on range land. Identify and mitigate high metal and mineral contact water in stock ponds.
o. Restrict access to forests within watersheds to reduce potential for forest fires.