APPENDIX E: ARIZONA CLIMATE AND DROUGHT

Appendix E
Arizona Climate and Drought

Climate

Arizona's climate is characterized by five main features: warm temperatures, aridity, strong precipitation seasonality, high year-to-year (interannual) variability and strong decade-to-decade persistence. The wide elevational differences result in significant climate variability between the mountains of the Central Highlands Province and the low elevation deserts. The Plateau Uplands Province, although relatively high in elevation, is very dry. Average annual rainfall in Arizona ranges from 3 inches in Yuma to over 36 inches in the higher elevations along the Mogollon Rim and in the White Mountains. State precipitation variability is shown in Figure 1-14.

There are two climatically unrelated precipitation seasons: the summer, "monsoon" season, generally from July to mid-September and a winter season from November through mid-April. This seasonality is more pronounced in the east-central (Central Highlands Planning Area) and southeastern (Southeastern Arizona Planning Area) parts of the state where the summer precipitation can account for up to 60 percent of the annual total. By contrast, the Upper Colorado River Planning Area receives the majority of precipitation in the winter. Statewide, mid-April through June are reliably dry, as westerly winds shift to the north and the monsoon circulation begins to develop. Mid-September through early November is usually dry, but eastern Pacific tropical storms can cause high precipitation during this time of year.

The summer precipitation season occurs when moist, tropical, unstable air from the Gulf of Mexico moves northwest into Arizona. Storms of short duration but high intensity occur in the afternoon and evening as the warm, moist air is forced up mountain slopes and sufficiently cooled. These storms are typically most intense over the mountainous sections of the state. Winter rains occur when middle latitude cyclonic storms originating in the Pacific Ocean move east across the state. More than 75% of the winter precipitation falls as snow in the higher elevations. (ADWR, 1994a).

The El Niño-Southern Oscillation (ENSO), a multi-season to multi-year variation in equatorial Pacific Ocean temperatures and associated atmospheric circulation, is the strongest and most important influence on interannual climate and weather variations in Arizona. When El Niño-Southern Oscillation is in the El Niño phase, Arizona frequently receives above average winter precipitation. When El Niño-Southern Oscillation is in the La Niña phase, Arizona is frequently dry due to a more northern storm track. These phases recur every 3 to 7 years on average and can persist for months to years, impacting precipitation totals over Arizona. During the past two decades, several La Niña episodes (e.g. 1989-90, 1995-96, 1998-2001) have initiated Arizona droughts (GDTF, 2004). The La Niña of 2005-2006 resulted in virtually no snowpack in Arizona until mid-March, with 29 of the 34 snow measuring sites monitored by the NRCS reporting no snow as of March 1, 2006, the least amount recorded since measurements began in the late 1930's.

Arizona's Colorado River water supplies derive primarily from snow in the Rocky Mountains of Wyoming, Colorado, and Utah, whereas Arizona surface water supplies, such as in the Salt and Verde River systems, derive chiefly from snow along the Mogollon Rim and high peaks on the Colorado Plateau.

Temperature and associated evapotranspiration rates also vary widely in Arizona. Average daily temperatures range from the mid 90's (˚F) below 500 feet elevation to the high 50's (˚F) at elevations above 8,000 feet. In most areas of the state, temperatures increase 30 to 40 degrees between January and July (ADWR, 1994a). Climate can also vary widely within planning areas. Measured climate data are described in detail in the planning area volumes.

The most significant feature of temperature records is the trend toward increasing temperatures during the last 30-40 years (Figure 1-5). In some regions, increased temperatures are due primarily to the urban heat island effect from heat-retaining paved area and buildings replacing desert landscapes in major urban areas. Temperatures in rural communities have also increased, though not at the same rate and not in every town. The mid-to-late twentieth century is the warmest period in a southern Colorado Plateau tree-ring temperature reconstruction (Salzer and Kipfmueller, 2005), as well as in reconstructions of summer season precipitation for a region stretching from west Texas to eastern California (Sheppard and others, 2002).

Drought

Decadal-scale Pacific Ocean circulation persistence can result in long-term drought, which can drastically reduce water supplies as demonstrated in the extremely dry conditions between 1999 and 2005 and during the 1950s. Table E-1 shows that 2004 was the year of lowest capacity in most of the state's reservoirs during the period of 1971-2005. When these sustained circulation patterns are characterized by warm tropical Pacific Ocean temperatures, the result can be above average precipitation such as the post-1976 wet period which lasted until approximately 1998 (Figure E-1). This wet period is also reflected in the high capacity reservoir level data in Table E-1. Some reservoirs, including Lake Powell and Lake Mead, exceeded their maximum useable capacity during this period and spilled.

When Arizona's high interannual precipitation variability is superimposed on persistent decadal variations, the result is individual wet years during periods of prolonged drought. This is shown in Figure E-1.

Table E-1 Arizona mean, high capacity and low capacity reservoir levels from 1971 through 2005, expressed in percent of total reservoir capacity (design flood pool)

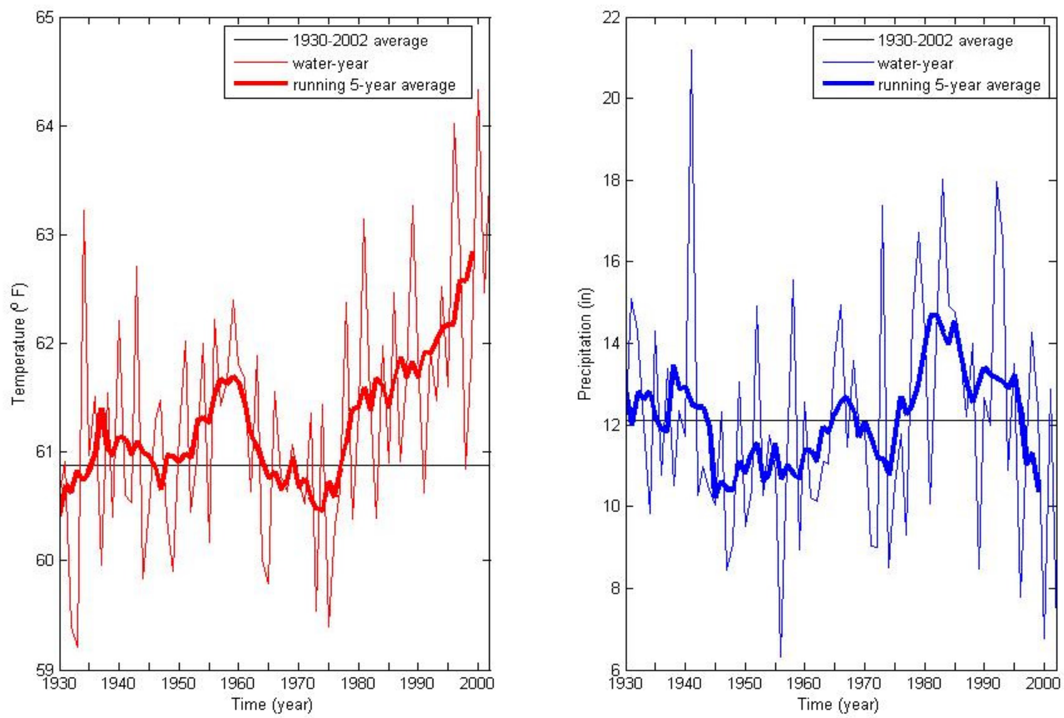
Reservoir Name	Average Capacity	High Capacity	High Capacity Year	Low Capacity	Low Capacity Year
Lake Powell	70%	98%	1983	31%*	2005
Lake Mead	77%	98%	1983	51%	2004
Lake Mohave	89%	98%	1971	74%	2000
Lake Havasu	88%	96%	1982	77%	1980*
Show Low Lake	62%	100%	1993	58%	2004
Lyman Reservoir	45%	86%	1985	11%	2004
San Carlos	42%	100%	1980	3%	2004
Verde River Basin System	56%	91%	1992	43%	2004
Salt River Basin System	59%	77%	1979	43%	2004

Sources: USDA Natural Resources Conservation Service, CLIMAS. BOR, and ADWR
* Lake Havasu 2004 low capacity was 79%

Tree-ring records of drought and winter precipitation show dry episodes longer and more severe than any that have occurred during the last 100 years. In Arizona, notable multi-year droughts occurred in almost every century in the last 1,000 years. Particularly notable are winter-season droughts during the 1100s, the 1200s, the early 1400s, the late 1500s, the late 1600s, the late 1700s, the late 1800s and the mid-1900s (Figure 1-16). Tree-ring records of Colorado River streamflow show periods of extended low flows, such as those in the 1580s, the early 1620s to 1630s, the 1710s, the 1770s, and the 1870s (C. Woodhouse, NOAA Paleoclimate Program, personal communication to G. Garfin, CLIMAS).

2005). These episodes were either more severe or longer in duration than low flow periods experienced in more recent times. The low flow period of the late 1500s is associated with widespread drought conditions across North America (Stahle et al., 2000).

Figure E-1 Average water-year (October-September) temperature (left) and total water-year precipitation in Arizona from 1930-2002

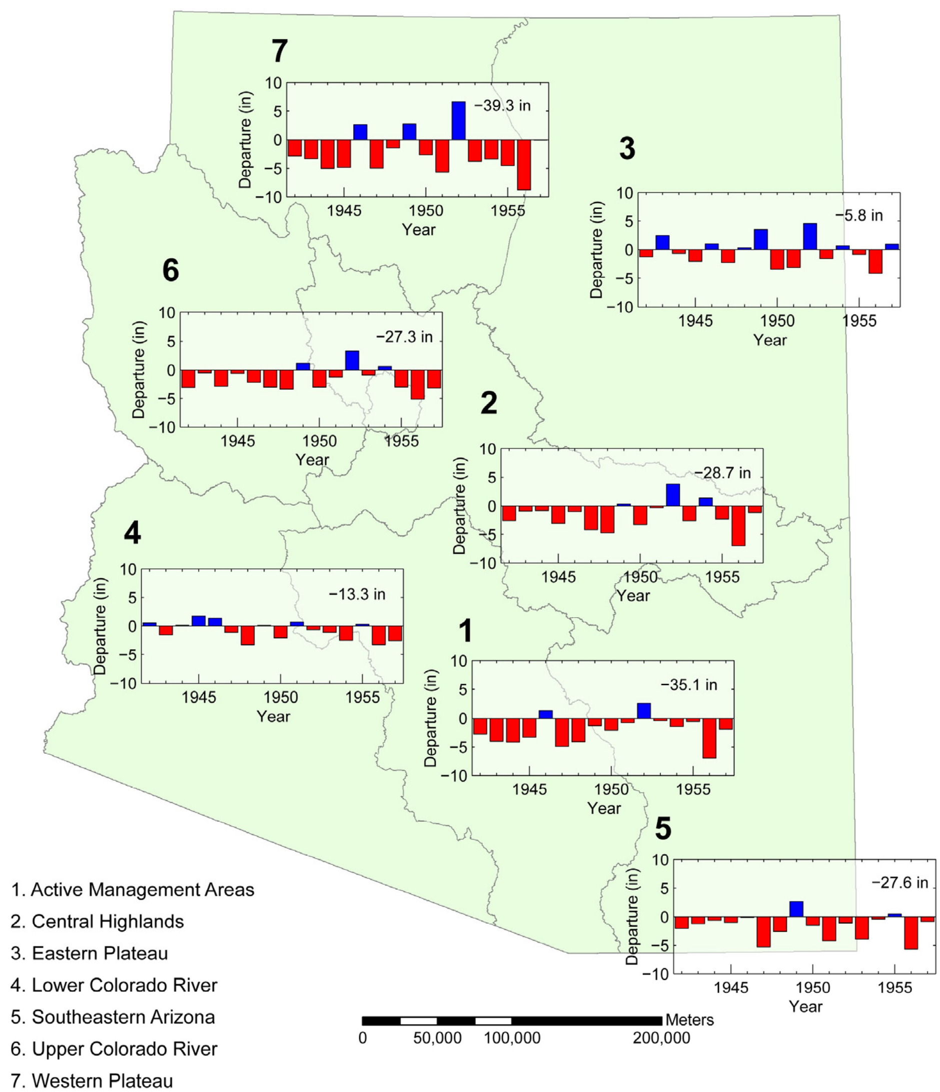


Horizontal lines are average temperature (60.9 °F) and precipitation (12.1 in), respectively. Light lines are yearly values and highlighted lines are 5-year moving average values. Data are the average of monthly records from 25 U.S. Historical Climate Network (HCN) stations from the National Climate Data Center. CLIMAS, 2006.

Such periods of widespread drought are characterized by low stream flows in the Upper Colorado River Basin as well as interior Arizona river basins, such as the Salt-Verde-Tonto river system. Records show that the Upper Colorado River Basin streamflow is seldom out of synch with Salt-Verde-Tonto river system streamflow (Hirschboeck and Meko, 2005). This has serious implications for water supply availability in parts of Arizona.

Planning area and AMA water deficits for the prolonged drought of 1942-1957 are shown in Figure E-2. It is evident that planning areas were affected to varying degrees during this period. For example, the Eastern Plateau Planning Area was the least impacted, with many years of above normal precipitation and a modest cumulative deficit of -5.8 inches over the drought period. While the current drought may reflect similar precipitation conditions to those of the drought of the late 1940s to 1950's, temperatures during the last decade are almost 2 degrees higher (see Figure E-1). This warming trend will affect the severity of drought conditions.

Figure E-2 Planning area water-year (October-September) precipitation departures from average for the 1942-1957 drought period



For each planning area, data from U.S. Historical Climate Network (HCN) stations from the National Climatic Data Center were used to calculate the total departure (upper right of each bar graph). CLIMAS, 2006.

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