ARIZONA WATER ATLAS
VOLUME 4
UPPER COLORADO RIVER PLANNING AREA

Arizona Department of Water Resources

DRAFT

March 2007

ARIZONA WATER ATLAS
VOLUME 4 - UPPER COLORADO RIVER PLANNING AREA

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Preface

Volume 4, the Upper Colorado River Planning Area, is the fourth in a series of nine volumes that comprise the Arizona Water Atlas. The primary objectives in assembling the Atlas are to present an overview of water supply and demand conditions in Arizona, to provide water resource information for planning and resource development purposes, and help identify the needs of communities.

The Atlas divides Arizona into seven planning areas (Figure 4.0-1). There is a separate Atlas volume for each planning area, an introductory volume composed of background information, and an executive summary volume. "Planning areas" are an organizational concept that provide for a regional perspective on supply, demand and water resource issues. A complete discussion of Atlas organization, purpose and scope is located in Volume 1.

Additional, more detailed data than those presented in this volume are available. They may be obtained by contacting the Arizona Department of Water Resources' Statewide Conservation and Strategic Planning Division.

4.0 Overview of the Upper Colorado River Planning Area

The Upper Colorado River Planning Area is composed of nine groundwater basins located in northwestern Arizona, south and east of the Colorado River. Elevation ranges from 450 feet to 8,417 feet. Most of the planning area is within Mohave County; the planning area includes smaller portions of Coconino, La Paz and Yavapai counties. Parts of the Fort Mojave and Hualapai Indian Reservations are within the planning area. The 2000 Census planning area population was approximately 153,800. Basin population ranged from 822 in the Meadview Basin to over 51,000 in the Lake Mohave Basin. Lake Havasu City is the largest metropolitan area with about 42,000 residents in 2000. Annual cultural water demand was about 173,650 acre-feet during the period 2001-2003. Agriculture is the largest water use sector in the planning area with an annual demand of approximately 95,850 acre-feet, almost entirely within the Lake Mohave Basin. Municipal demand accounts for about 55,200 acre-feet/year, and industrial demand is about 22,600 acre-feet/year.

4.0.1 Geography

The Upper Colorado River Planning Area encompasses about 11,860 square miles and includes the Big Sandy, Bill Williams, Detrital Valley, Hualapai Valley, Lake Havasu, Lake Mohave, Meadview, Peach Springs and Sacramento Valley basins. Basin boundaries, counties and prominent cities, towns and places are shown in Figure 4.0-2. The planning area is bounded on the north by the Colorado River, the state of Nevada and by the Western Plateau Planning Area, on the east by the Central Highlands Planning Area and the Prescott Active Management Area, on the south by the

Lower Colorado River Planning Area and a portion of the Central Highlands Planning Area and on the west by the Colorado River and the states of California and Nevada. The planning area includes all or part of five watersheds, which are discussed in section 4.0.2. Within the planning area, the Fort Mojave Indian Reservation encompasses about 23,500 acres and the Hualapai Indian Reservation encompasses about 553,000 acres. Elevation ranges from 450 feet along the Colorado River near Lake Havasu City to 8,417 feet at Hualapai Peak south of Kingman.

Arizona's three physiographic provinces are found in the planning area (See Volume 1, Figure 1-2). Most of the planning area is within the Basin and Range physiographic province, which is characterized by northwest-southeast trending mountain ranges separated by broad alluvial valleys. The Detrital Valley and Sacramento Valley basins are representative of this province. The northeastern portion of the planning area, primarily the Peach Springs Basin, falls within the Plateau Uplands physiographic province, characterized by high desert plateaus and incised canyons. The eastern portion of the planning area that includes the eastern, upland areas of the Big Sandy and Bill Williams basins is located within the Central Highlands physiographic province, characterized by rugged mountains of igneous, metamorphic and sedimentary rocks.

Unique geographic features of the planning area are the Colorado River and associated lakes impounded by several dams. The River and lakes define its northern and western boundaries and influence the cultural uses, groundwater conditions and habitat in a significant portion of the planning area.

4.0.2 Hydrology[1]

Groundwater Hydrology

The Upper Colorado River Planning Area is characterized by semi-arid, alluvial basins with few perennial streams. Anderson, Freethey and Tucci (1992) divided the alluvial basins in south-central Arizona into categories based on similar hydrologic and geologic characteristics. These categories are useful in describing general hydrologic characteristics. Although their study basins do not match the Department's groundwater basins exactly, the area encompassed by the Upper Colorado River Planning Area basins is included in their study with the exception of Peach Springs Basin. Four basin categories identified by Anderson, et al. are represented in the planning area. Basins are categorized as either "West", "Colorado River", "Highland" or "Southeast" and are discussed below.

<u>West Basins</u>

The West basins include the Detrital Valley, Hualapai Valley, and Meadview basins, most of the Sacramento Valley Basin and part of the Bill Williams Basin (see Figure 4.0-2). These basins are the most arid regions in the planning area. Groundwater inflow and outflow are small and there is almost no stream baseflow.

In the Detrital Valley Basin, groundwater occurs mostly in basin-fill material and in alluvial deposits along mountain washes. Intermediate and younger basin fill are above the water table

[1] Except as noted, much of the information in this section is taken from the Arizona Water Resources Assessment, Volume II, ADWR August, 1994.

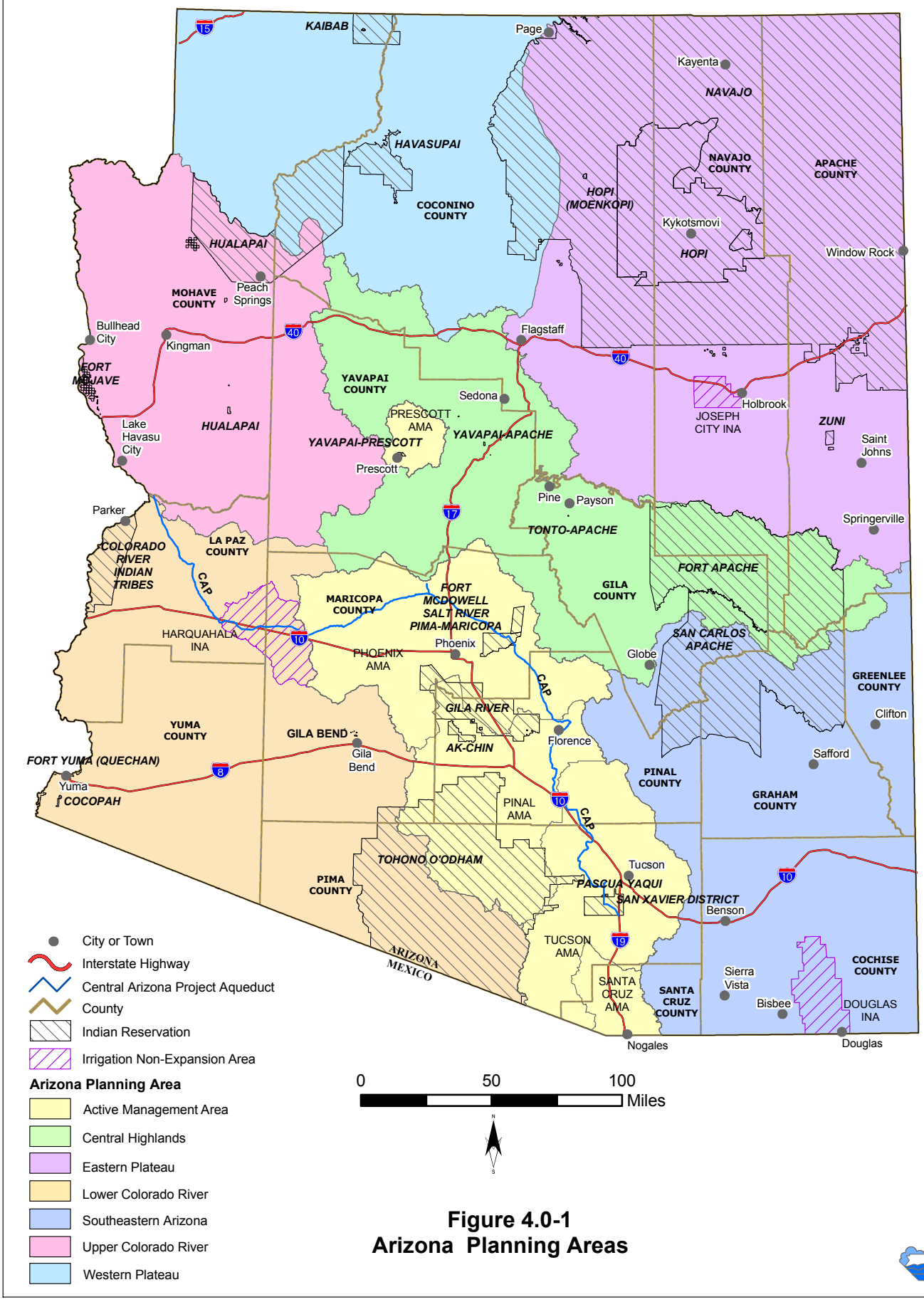


Figure 4.0-1
Arizona Planning Areas

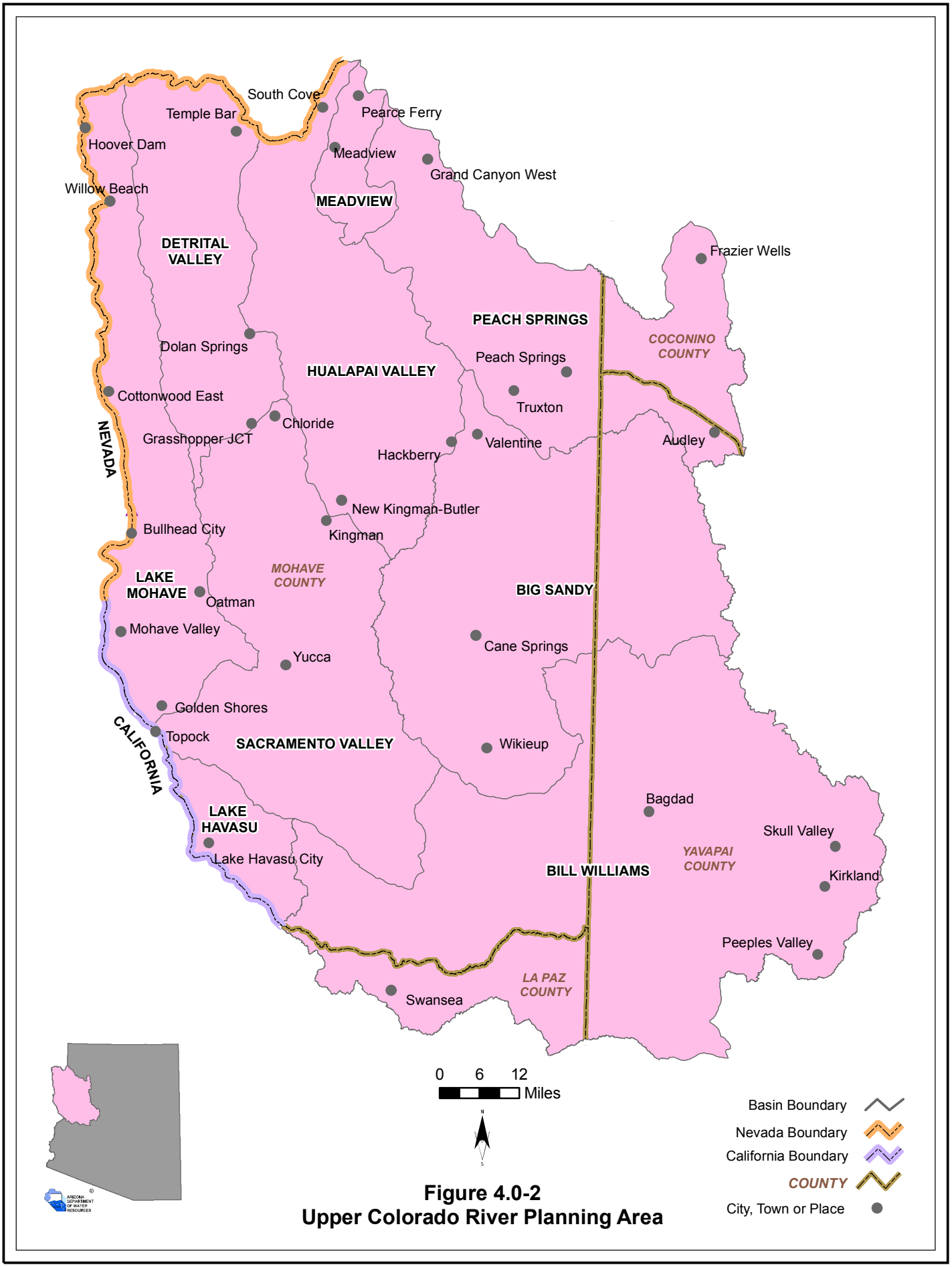


Figure 4.0-2
Upper Colorado River Planning Area

in most areas so the older basin fill aquifer is the primary water supply. In the northern part of the basin, the basin fill includes clastic (weathered) sediments, limestone, and basalt flows of the Muddy Creek and Chemehueve Formations (USGS, 2006). Depth to bedrock may exceed 6,000 feet at the deepest point. There is a clay unit that may extend from 600 to 1,400 feet below land surface in the central portions of the basin. It acts as an impediment to groundwater flow and reduces the amount of recoverable groundwater due to its low specific yield. The areal extent of this unit is not well known due to lack of data (ADWR, 2006).

The Hualapai Valley Basin has relatively deep, basin fill sediments categorized into three units. The younger alluvium unit includes recent streambed deposits in Hualapai Valley and in mountain canyons. This unit yields small volumes of water to stock and domestic wells. The intermediate alluvium, which is composed of coarse-grained sands, silts and clays, is a dependable aquifer only along the valley margins where the unit intersects the water table. As with other basins in this category, the older alluvium is the primary water supply. Similar to the Detrital Valley Basin located to the west, the northern part of the valley includes clastic sediments, limestone and basalt flows of the Muddy Creek and Chemehueve Formations within the basin fill (USGS, 2006). Recharge to the aquifer comes primarily from streambed infiltration. Groundwater is highly mineralized in some areas near the mountains and near Red Lake, a dry lakebed. Chromium has been detected in some wells in the basin.

The main aquifer in the Meadview Basin is the Muddy Creek Formation composed of three units. The upper limestone unit yields water to shallow wells and springs. The middle sandstone unit has a high clay content that limits its ability to transmit water. The lower unit is a conglomerate with high hydraulic conductivity. Most well development is in this lower unit. Groundwater recharge is relatively small due to low rainfall and high evaporation rates. Groundwater quality is generally good in the basin.

Older alluvium is the principal aquifer in the Sacramento Valley Basin. Aquifer recharge is from infiltration of runoff in washes and along mountain fronts, except in the vicinity of the Colorado River where infiltration of river water is the main source of recharge. There are fractured and faulted volcanic rocks in the vicinity of Kingman that separate this basin from the Hualapai Valley Basin. Little water is pumped from wells located in these volcanics. The fractured granite aquifer beneath the community of Chloride is insufficient to meet its needs and water must be hauled from Kingman. In addition, concentrations of radionuclides in Chloride wells have exceeded Safe Drinking Water Act maximum contaminant levels (City of Kingman, 2003). Otherwise, groundwater quality is generally good in the basin except along the base of the mountains where waters of high mineral content are common.

Anderson, Freethey and Tucci (1992) categorized most of the western portion of the Bill Williams Basin as a “West” basin, which generally corresponds to the Alamo Reservoir and Clara Peak sub-basins (see Figure 4.2-6). Groundwater in this area occurs primarily in younger alluvial deposits and in basin fill. The water-bearing ability of these units varies within the basin. The younger alluvium consists of gravel, sand and silt along the Bill Williams River and its major tributaries. The main water-bearing unit is the basin fill and water quality within this unit is generally good. Basin fill deposits more than 5,000 feet thick are found in the Bullard Wash-Date Creek Area southeast

of Alamo Lake State Park. Recharge is from streamflow and mountain front precipitation.

Colorado River Basins

The Colorado River Basins include the Lake Havasu and Lake Mohave basins and portions of the Sacramento Valley and Bill Williams basins in the vicinity of the Colorado River. In these areas the direction and occurrence of groundwater are influenced by the amount of streamflow in the Colorado River. Infiltration of river water is the main source of inflow to aquifers. The aquifers are composed primarily of stream alluvium deposits that are hydraulically connected to the underlying older alluvium. Groundwater occurs under unconfined conditions in both the stream and older alluvium.

In the Lake Havasu Basin the basin fill alluvium, consisting of sand, silt and gravel, overlies the Bouse Formation (siltstone and fine-grained sandstone) and a conglomerate unit. Most wells in the basin penetrate the upper 100-200 feet of the basin fill. There is a direct hydraulic connection between the Colorado River, Lake Havasu and groundwater in the basin.

The principal water-bearing formations in the Lake Mohave Basin are alluvial sand, silt and gravel deposits adjacent to Lake Mohave and the Colorado River. The regional groundwater level is higher than it was prior to filling Lake Mohave upstream of Davis Dam, but the general groundwater flow direction is still toward the west. A granite ridge extends across the Colorado River and basin near Davis Dam, restricting recharge from the lake to the south. In general all groundwater is unconfined in the basin. Compared with aquifer recharge from the lake, mountain front recharge is negligible. There are occurrences of high total dissolved solids (TDS) and fluoride along the mountain fronts. Thermal and other springs occur downstream of Hoover Dam and represent the only surface water in the basin other than the lake and the Colorado River.

Highland Basins

The aquifers of the Highland basins, which generally encompass the northeastern portions of the Big Sandy and Bill Williams basins, consist of hydraulically connected basin fill and younger alluvium. These aquifers tend to be discontinuous and limited in extent. Groundwater inflow is from adjacent consolidated rock aquifers, stream channels, and mountain front recharge. Groundwater outflow is due to evapotranspiration and baseflow to streams (Anderson, et al. 1992).

In this portion of the Big Sandy Basin, generally the Fort Rock sub-basin, (see Figure 4.1-6), the primary hydrologic unit consists of sedimentary rocks composed of Redwall Limestone (a coarse-grained, massive limestone) and the Martin Formation (a fine- to coarse-grained dolomitic limestone). The limestone forms a regional aquifer that extends north and east. There is little water development in this portion of the Big Sandy Basin.

Groundwater in the northeastern portion of the Bill Williams Basin, generally the Burro Creek, Santa Maria and Skull Valley sub-basins (see Figure 4.2-6), is found in basin fill, in fractured and porous volcanic rocks and in younger alluvial deposits. In the Peeples Valley area, the younger alluvium is the main water-bearing unit. An important water-bearing unit in the Copper Basin area east of Skull Valley is a 1,000 foot thick layer of volcanic rocks with reportedly high yields in the upper 350 to 400 feet. Recharge occurs from streamflow and mountain front precipitation. Other

sources of groundwater are from faults in granite and metamorphic rocks. Springs are found in volcanic and crystalline rocks in the area including along Burro Creek.

Southeast Basins

With the exception of its northeastern portion, most of the Big Sandy Basin was categorized as a "Southeast" basin by Anderson, Freethey and Tucci (1992). This area generally corresponds to the Wikieup sub-basin south of Interstate 10 (see Figure 4.1-6). Southeast basins are characterized by moderately thick pre-Basin and Range sediments and an overlying layer of lower basin fill to depths of over 1,000 feet. Aquifers generally consist of two or more water-bearing units separated by a fine-grained unit that forms a leaky confining layer over the lower basin fill. Primary water development in the Big Sandy Basin is along the central valley, primarily in the upper basin fill that varies from loosely consolidated silty gravel to sandy silt. The floodplain alluvium in the central valley is 30-40 feet thick and is an unconsolidated deposit of gravel and sand. In the Wikieup area, wells greater than 40 feet in depth tap the upper basin fill, which is estimated to be 300 feet deep in that area. North of Wikieup, the upper basin fill is estimated to be 150 to 200 feet deep.

Peach Springs Basin

The Peach Springs Basin was not included in the study conducted by Anderson, Freethey and Tucci (1992). This basin is characterized by an upland area, the Hualapai Plateau, in the western part of the basin, composed of interbedded limestones, shales and sandstones, and by Aubrey and Truxton Valleys that are filled with recent lava flows and alluvial material (See Figure 4.8-1). The Muav limestone is the main water-bearing unit on the Hualapai Plateau where depths to groundwater may be as much as 1,300 feet. Groundwater flow is toward the northeast. It exits the basin at springs emanating from the Muav limestone in the Grand Canyon. Groundwater is limited to a few permeable layers in the basin's two primary valleys. In the Aubrey Valley in the far northeastern part of the basin near Frazier Wells, groundwater is found in gravel beds at relatively shallow depth. In the Truxton Valley area, lake-bed deposits are a local source of groundwater. In some areas of the basin, Precambrian rocks, isolated volcanic rocks and local alluvial sands in washes provide small amounts of water.

Surface Water Hydrology

The U.S. Geological Survey (USGS) divides and subdivides the United States into successively smaller hydrologic units based on hydrologic features. These units are classified into four levels. From largest to smallest these are: regions, subregions, accounting units and cataloging units. A hydrologic unit code (HUC) consisting of two digits for each level in the system is used to identify any hydrologic area (Seaber et al., 1987). The 6-digit unit code corresponds to accounting units, which are used by the USGS for designing and managing the National Water Data Network. One USGS 6-digit HUC watershed is completely within the planning area - Bill Williams. In addition, there are portions of four others: the Lower Colorado-Lake Mead; the Lower Colorado below Lake Mead; the Lower Gila-Agua Fria; and the Verde (Figure 4.0-3).

Lower Colorado-Lake Mead

The Lower Colorado-Lake Mead watershed is located in the Western Plateau Planning Area and in the northern portion of the Upper Colorado River Planning Area. Included within the Upper Colorado River Planning Area portion of the watershed are the Hualapai Valley and Meadview basins, almost all of the Detrital Valley Basin, all but the far eastern portion of the Peach Springs Basin and the northern-most part of the Big Sandy Basin.

The major north-flowing tributaries to the Colorado River in the Upper Colorado River Planning Area portion of the watershed are Hualapai Wash in the Hualapai Valley Basin, and Detrital Wash in the Detrital Valley Basin. These washes are ephemeral and contribute little to the flow of the Colorado River. The other major wash is Truxton Wash in the Peach Springs and Hualapai Valley basins, which flows north to Red Lake, a dry lake. The Colorado River is the only perennial water supply in the watershed portion of the planning area (AGFD, 1993 & 1997). There is only one intermittent stream, a portion of Truxton Wash, located in Peach Springs Basin.

Lake Mead, created by Hoover Dam, has affected groundwater conditions in adjacent basins in the watershed. There is outflow from the lake into the surrounding aquifers. Lake Mead extends from Hoover Dam in the Lake Mohave Basin, along the planning area boundary to Peach Springs Basin. Maximum storage in Lake Mead is 29.7 million acre-feet (maf). Of this, 2,378,000 maf is "dead storage" - the reservoir capacity from which stored water cannot be evacuated by gravity. The average storage during the period from 1996 to 2005 was 20.3 maf.

Twenty-four major springs (springs with a measured discharge rate of 10 gallons per minute [gpm] or greater at any time) are found in the watershed, primarily located in the Peach Springs and Meadview basins. Generally, springs with the greatest discharge are located in the Hualapai Plateau in the Peach Springs Basin, where discharges of 1,730 gpm at Spencer Spring and 1,233 gpm at Meriwhitica Spring have been measured. With the exception of a number of springs measured in the early 1990s, particularly in the Peach Springs Basin, most of the spring measurements were recorded over 30 years ago and may not reflect current conditions. For example, recent discharge measurements taken at two "major" springs in the Peach Springs Basin were less than 10 gpm. (See Springs tables in each basin section.)

There is only one streamgage in the watershed at Spencer Creek near Peach Springs. Median flows at this gage are about 1,500 acre-feet per year.

Lower Colorado below Lake Mead

This watershed consists of two sections in Arizona. The northern portion is within the Upper Colorado River Planning Area (north watershed) and the southern portion is located in the Lower Colorado River Planning Area. Groundwater basins included in the north watershed are the Lake Havasu Basin and most of the Lake Mohave and Sacramento Valley basins. A very small portion of Detrital Valley Basin also lies within the north watershed. Sacramento Wash an emphemeral wash in the Sacramento Valley Basin is the only major contributing tributary to the Colorado River in the north watershed. Sawmill Canyon, located at the northeastern edge of the Sacramento Valley Basin, is the only intermittent stream.

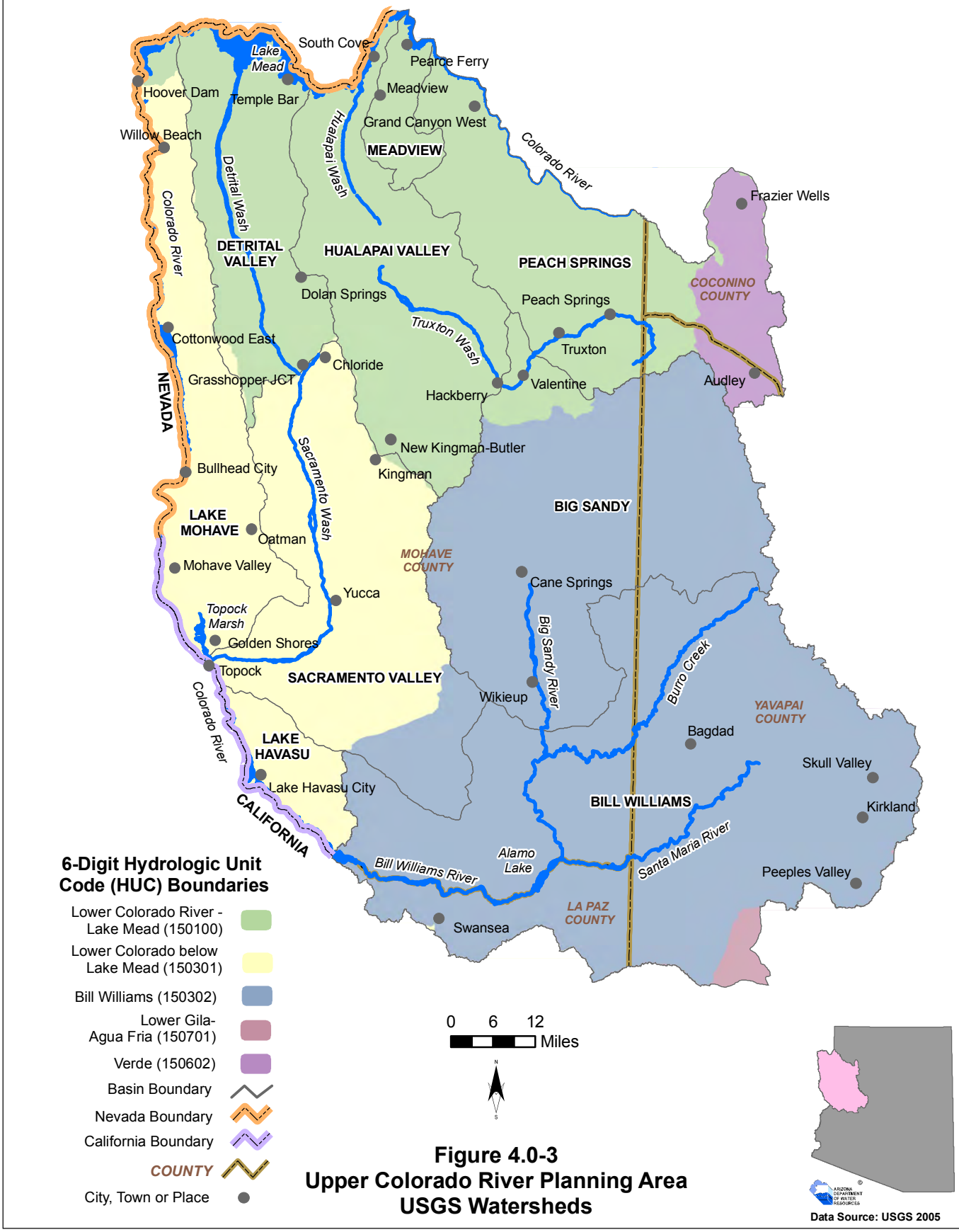


Figure 4.0-3
Upper Colorado River Planning Area
USGS Watersheds

Parker and Davis dams have created lakes that affect groundwater conditions along the Colorado River. Parker Dam is located in the Lower Colorado River Planning area but the lake it creates, Havasu, extends into the Upper Colorado River Planning Area. Davis Dam, north of Bullhead City, creates Lake Mohave. There is outflow from the river and lakes into the surrounding aquifers. Maximum storage in Lake Mohave is about 1.8 maf (including dead storage) and average storage from 1996 to 2005 was 1.65 maf. Maximum storage in Lake Havasu is 651,000 acre-feet (including dead storage) and average storage from 1996-2005 was about 572,000 acre-feet.

The only streamgages in the north watershed are along the Colorado River. Streamflow is largely subject to releases from upstream dams. A gage at Topock reports median annual flow of 8.9 maf, a gage below Davis Dam reports median annual flow of 8.5 maf, and median annual flows below Hoover Dam are 9.2 maf.

Twenty-four major springs (those with a measured discharge rate of 10 gpm or greater at any time) are found in the north watershed. These springs are located in the northern half of the Sacramento Valley Basin and in the Lake Mohave Basin along the Colorado River immediately below Hoover Dam. Only three of the major springs have had a measured discharge rate of 100 gpm or greater. There are a relatively large number of minor springs (42) in the Sacramento Valley Basin. The most recent spring measurements were taken in 1979 and some measurements date to the 1940s.

Bill Williams

The Bill Williams watershed has a drainage area of about 5,393 sq. miles (NEMO, 2005). The watershed drains into Lake Havasu just upstream of Parker Dam near the southern boundary of the planning area. The greatest elevational range in the planning area, from 8,417 feet at Hualapai Peak to 450 feet north of Parker Dam, is found in the watershed. The watershed includes the Bill Williams Basin, most of the Big Sandy Basin and the southern portion of the Sacramento Valley Basin. The watershed is drained by the Bill Williams River and its major tributaries, the Big Sandy and the Santa Maria Rivers and by Burro Creek. A number of perennial streams exist in the watershed including segments of the Big Sandy River, the Bill Williams River, Burro Creek, Kirkland Creek, the Santa Maria River, and Trout Creek. Numerous intermittent streams also are present.

Construction of Alamo Dam on the Bill Williams River in 1968 significantly impacted streamflow below the dam. The dam is operated in a manner to benefit downriver wildlife refuges and vegetation along the river. According to NEMO (2005), only about 185 miles of perennial streamflow exist in the watershed, mostly restricted to the main stem of the Bill Williams River. Water levels in the Bill Williams River below Alamo Dam occasionally are affected by the water levels in Lake Havasu. Alamo Lake is the largest lake in the watershed with about 13,400 acres of open water surface.

Median annual streamflow in the Bill Williams River below Alamo Dam is about 34,000 acre-feet, but a maximum flow of almost 702,000 acre-feet was recorded in 1993. By comparison, the median annual flow at a gage on the Santa Maria River upstream of the dam is about 10,000 acre-feet a year. The median annual flow recorded at a gage south of Wikieup on the other major tributary to the Bill Williams River, the Big Sandy River, is about 27,000 acre-feet.

Within the watershed, perennial streams originate from spring water discharges from crystalline rocks. Most of the public water supply for the town of Bagdad comes from spring flow that discharges to Francis Creek, a tributary to Burro Creek. Twelve large springs have been identified in the watershed, with the largest located in the Big Sandy Basin. Discharge from an unnamed spring south of Cane Springs has had a discharge of 1,600 gpm. The largest spring in the Bill Williams Basin was measured at 228 gpm. There are no large springs reported in the Sacramento Valley Basin portion of the watershed. Most springs are located in the vicinity of Valentine, along the Big Sandy River, and near the eastern boundary of the Bill Williams Basin. All measurements were taken prior to 1980 and some measurements are as old as 1943; therefore, the reported discharges may no longer be representative of current conditions.

Verde

A very small portion of the Verde watershed extends into the easternmost portion of the Peach Springs Basin. There are no major tributaries, perennial or intermittent streams, or springs in this area.

Lower Gila-Agua Fria

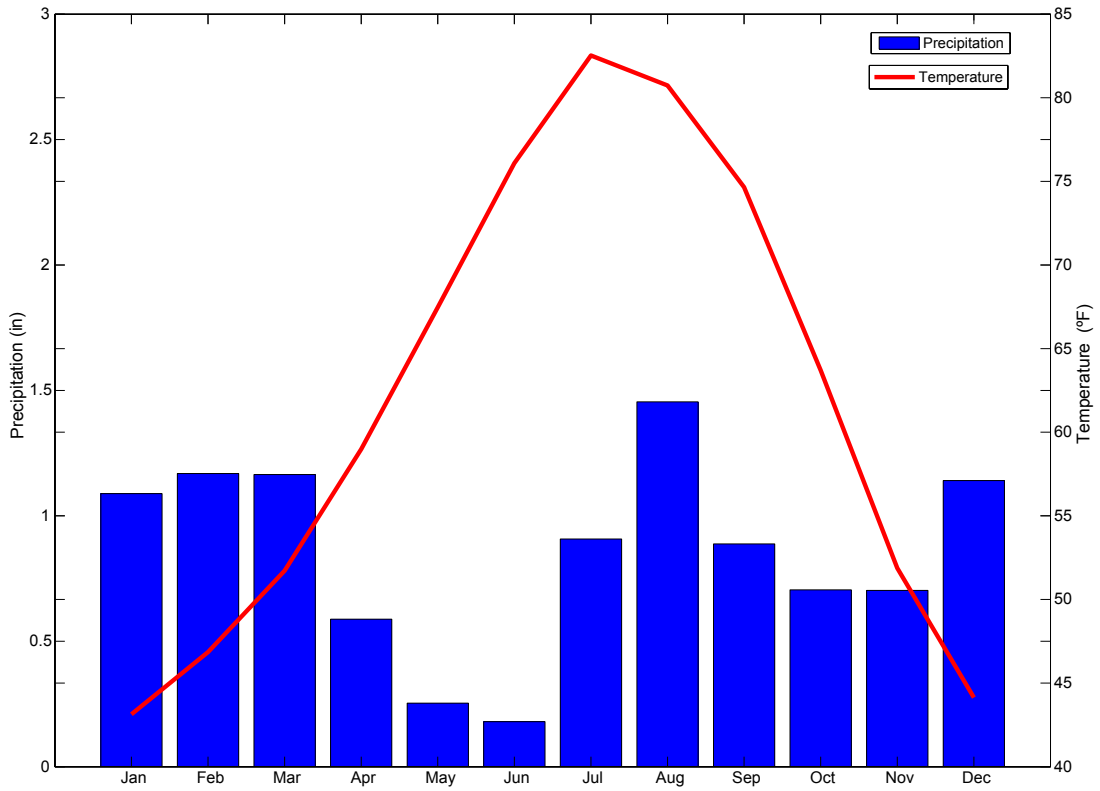
A very small portion of this watershed extends into the extreme southeastern portion of the Bill Williams Basin. There are no major tributaries, perennial or intermittent streams, or springs in this area.

4.0.3 Climate

The Upper Colorado River Planning Area has a distinctive bi-modal precipitation pattern found in other regions of the state, though this planning area is overall relatively dry. Summer precipitation peaks in August during the summer monsoon thunderstorm season. There is a secondary peak during December, and the May-June period is typically extremely dry. The area receives 58% of its precipitation on average during winter months (November-April), and higher elevations (e.g. Hualapai and Cerbat Mountains) typically receive some snow. From 1930-2002, average precipitation in Kingman was 10.2 inches, with 32% coming in July, August, and September (Figure 4.0-4). Average precipitation along the Colorado River is much lower, with an average of 4.9 inches recorded at Lake Havasu City from 1967-1991 and an average of 2.9 inches from 1991 to 2003. Kingman is the only location in the planning area with long-term weather records.

Precipitation patterns in Kingman generally are representative of the planning area. As in other areas of Arizona, precipitation is extremely variable, both spatially and temporally. For example, in 1988 Kingman recorded 13.3 inches of precipitation; in 1989 the total was 4.3 inches. This variability also may be observed on longer time scales. The 1950s and 1960s were relatively dry decades with an average annual precipitation deficit of -0.95 inches, while the 1980s was a relatively wet decade with an average annual precipitation surplus of 1.42 inches (Figure 4.0-5).

Figure 4.0-4 Average monthly precipitation and temperature in Kingman, Arizona, 1930-2002

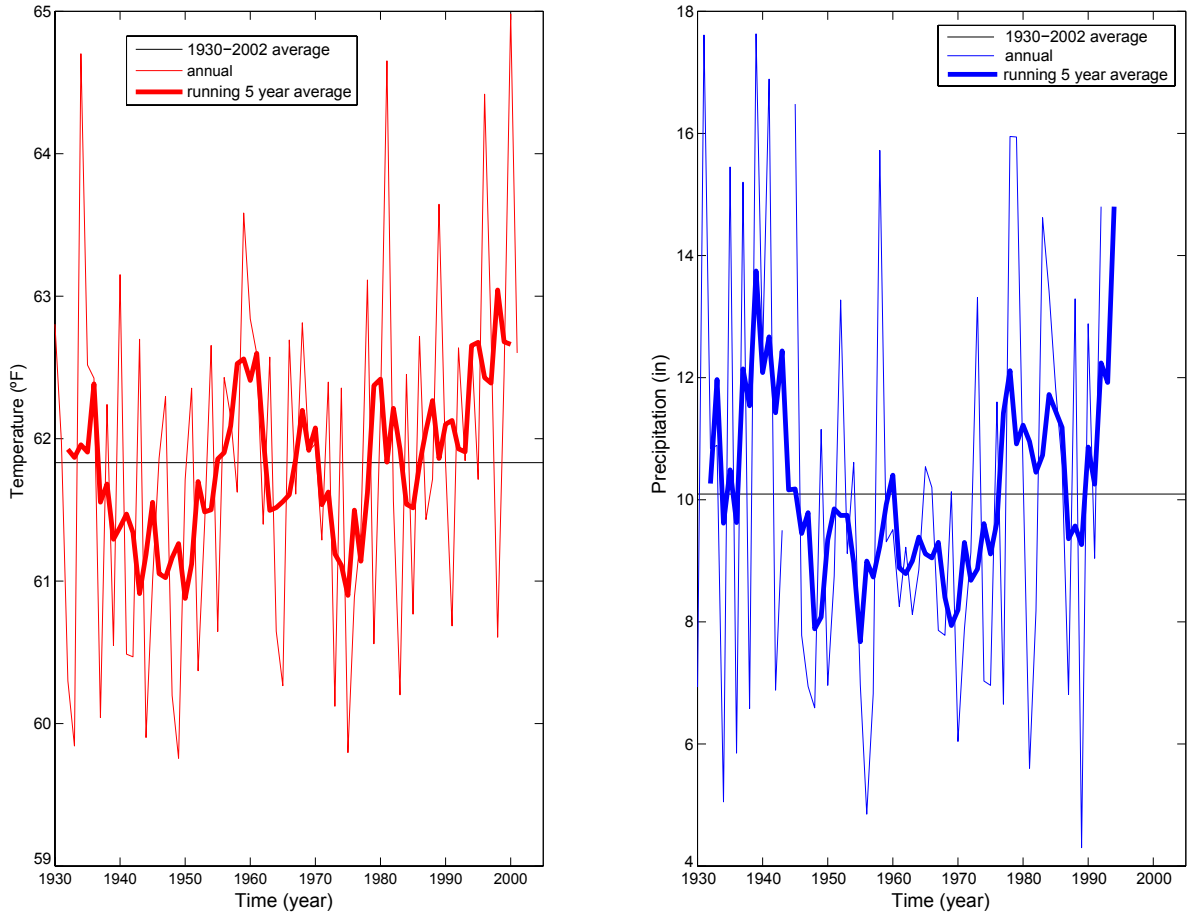


Data are from the U.S. Historical Climatology Network Figure author: Ben Crawford, CLIMAS

Winter precipitation records dating to 1000 A.D. have been reconstructed from tree rings. They show extended periods of above- and below- average precipitation in every century in the area defined by the National Oceanic and Atmospheric Administration (NOAA) as Climate Division 1, which corresponds to Mohave County (Figure 4.0-6). A climate division is a region within a state that is generally climatically homogeneous. Arizona is divided into 7 climate divisions.

Precipitation variability on time scales of 10-30 years likely is related to shifts in Pacific Ocean circulation patterns, such as the El Niño Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO). The ENSO phases, El Niño and La Niña, impact precipitation in the planning area. During El Niño episodes, there are greater chances for above-average winter precipitation as storm tracks across North America shift farther south than normal. La Niña conditions usually are associated with below-average winter precipitation.

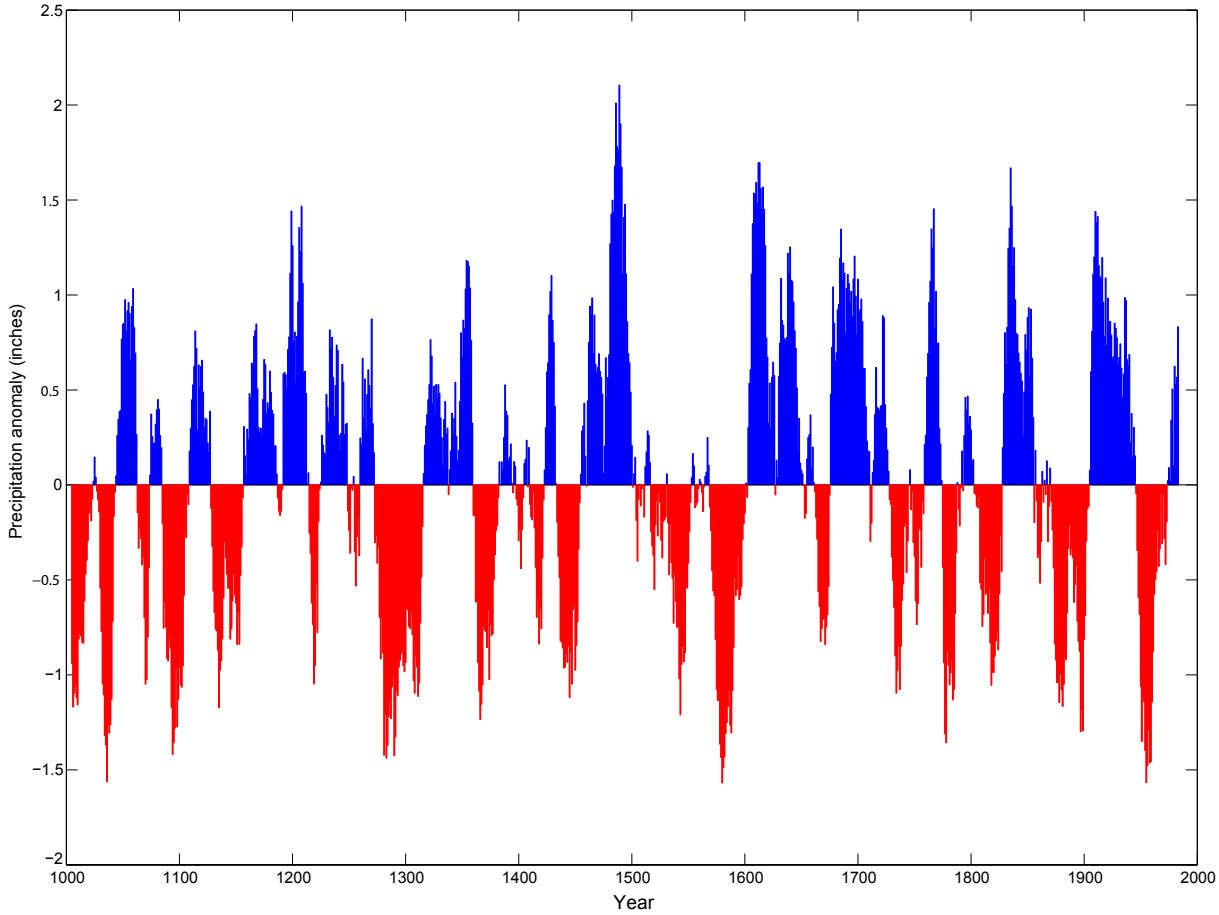
Figure 4.0-5 Average temperature (left) and total precipitation in Kingman, Arizona from 1930-2002



Horizontal lines are average temperature (61.9 °F) and precipitation (10.2 inches), respectively. Light lines are yearly values and highlighted lines are 5-year moving average values. Data are from U.S. Historical Climatology Network. Figure author: Ben Crawford, CLIMAS

Annual average temperature in Kingman is 61.9° F, compared to the statewide average of 59.9° F. The annual average temperature in Bullhead City for the period 1977 to 2006 was 74.2°F. As in other planning areas, temperatures have been increasing the past several decades (Figure 4.0-5), consistent with global temperature trends. Some warming may be attributed to changes in land-cover resulting from population growth.

Figure 4.0-6 Arizona NOAA Climate Division 1 (Mohave County) winter (November-April) precipitation departures from average, 1000-1988, reconstructed from tree rings



Data are presented as a 20-year moving average to show variability on decadal time scales. The average winter precipitation for 1000-1988 is 5.4 inches. Data: Fenbiao Ni, University of Arizona Laboratory of Tree-Ring Research and CLIMAS. Figure author: Ben Crawford, CLIMAS.

4.0.4 Environmental Conditions

Four of Arizona's five ecoregions are represented in the Upper Colorado River Planning Area: the Mohave Desert, Sonoran Desert, Colorado Plateau and the Apache Highlands (North). Therefore, the planning area is extremely diverse in terms of biotic communities, ranging from lowland Sonoran desertscrub to pine forests. Much of the area vegetation is Mohave and Sonoran desertscrub and semidesert grassland.

The largest yucca species, the Joshua tree, characterizes the Mohave Desert. The Mohave is a transitional desert between the higher and cooler Great Basin Desert and the lower, hotter Sonoran Desert. The Sonoran Desert ecoregion occurs in the extreme southern part of the planning area where the saguaro is the characteristic plant and biodiversity is quite high. In the Colorado Plateau

and Apache Highlands ecoregions, desert grasslands occur between elevations of 3,500 and 5,000 feet where annual precipitation is between 10 to 15 inches. These grasslands, which also contain shrubs and small trees, usually occur in basins and valleys near hills and mountain ranges between the desert and the woodlands. Pinyon-juniper woodlands cover areas between 5,500 and 7,000 feet and receive 12 to 20 inches of precipitation annually. The pine forest habitat, dominated by Ponderosa pine, occurs at elevations between 6,000 and 9,000 feet where precipitation is approximately 18 to 26 inches annually (Arizona Game and Fish, 2004).

Arizona Water Protection Fund Programs

Six riparian restoration projects in the Upper Colorado River Planning Area have been funded by the Arizona Water Protection Fund Program (AWPF) through 2005. The objective of the AWPF program is to provide funds for protection and restoration of Arizona's rivers and streams and associated riparian habitats. There are funded projects in three of the nine planning area basins. Four projects have been funded in the Bill Williams Basin and one each in the Big Sandy and Lake Mohave basins. A list of projects and types of projects funded in the Upper Colorado River Planning Area through 2005 is located in Appendix A of this volume. (A description of the program, a complete listing of all projects funded, and a reference map is found in Appendix C of Volume 1).

Instream Flow Claims

Seven applications for instream flow claims have been filed in the Upper Colorado River Planning Area, listed in Table 4.0-1 and shown on Figure 4.0-7. An instream flow right is a non-diversionary appropriation of surface water for recreation and wildlife use. Claims were filed only in the Bill Williams Basin, and certificates or permits were issued for claims on the Bill Williams River, Kirkland Wash and People's Canyon Creek.

Table 4.0-1 Instream flow claims in the Upper Colorado River Planning Area

Map Key	Stream	Applicant	Application No.	Permit No.	Certificate No.	Filing Date
1	Big Sandy River	BLM (Phoenix)	33-96348.0	Pending	Pending	2/8/1994
2	Bill Williams River	U.S. Fish & Wildlife Service	33-96300.0	96300	96300	9/13/1993
3	Bill Williams River	BLM (Phoenix)	33-94245.0	Pending	Pending	4/4/1988
4	Burro Creek	BLM (Phoenix)	33-89119.0	Pending	Pending	4/3/1984
5	Francis Creek	BLM (Phoenix)	33-96510.0	Pending	Pending	4/3/1984
6	Kirkland Wash	W & L Collier Ranch LP	33-95476.1	95476	95476	9/13/1990
7	People's Canyon Creek	BLM (Phoenix)	33-90410.0	90410	NA	3/24/1986

Source: ADWR 2005a
NA = Not Applicable

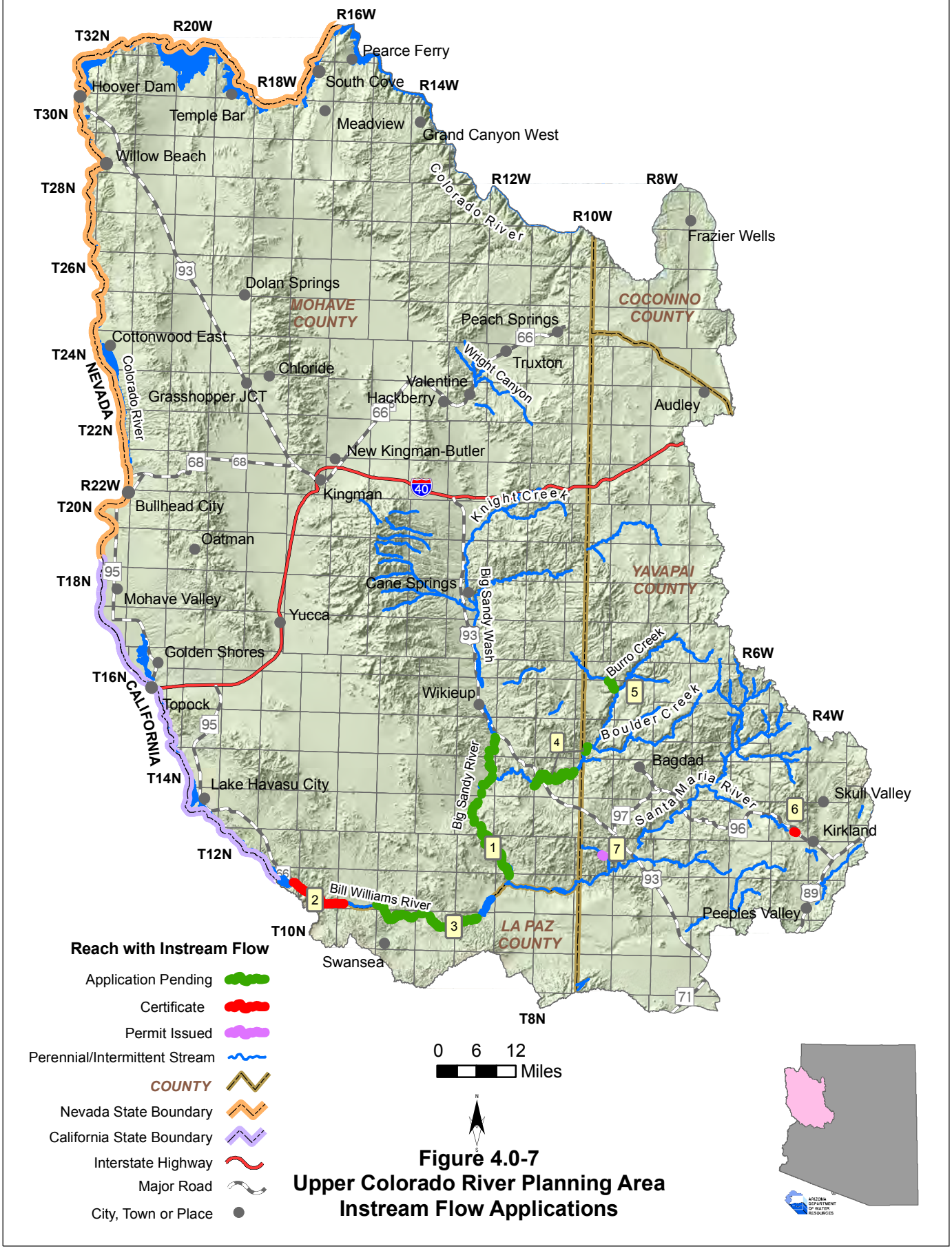


Figure 4.0-7
Upper Colorado River Planning Area
Instream Flow Applications

Threatened and Endangered Species

Listed threatened and endangered species appear to be present in the Upper Colorado River Planning Area. The species listed by the U.S. Fish and Wildlife Service (USFWS) as of May 2006 are shown in Table 4.0-2.[2] Presence of a listed species may be a critical consideration in water resource management and supply development in a particular area. The USFWS should be contacted for details regarding the Endangered Species Act (ESA), designated critical habitat and current listings.

Table 4.0-2 Listed threatened and endangered species in the Upper Colorado River Planning Area

Common Name	Threatened	Endangered	Elevation/Habitat
Arizona cliffrose		X	< 4,000 ft/ white soils of tertiary limestone lakebed deposits
Bald Eagle	X		Varies/large trees or cliffs near water
Bonytail chub		X	<4,000 ft/warm, swift, turbid mainstem rivers of the Colorado River area
California brown pelican		X	Varies/lakes and rivers
California condor		X	Varies/high desert canyon lands and plateaus
Desert pupfish		X	<5,000 ft/shallow springs, small streams and marshes
Desert tortoise, Mohave population	X		500-5100 ft/Mohave desertscrub north and west of the Colorado River
Gila topminnow		X	<4,500 ft/small streams, springs and cienegas
Hualapai mexican vole		X	3,500-7,000 ft/grass forb habitats in ponderosa pine
Mexican spotted owl	X		4,100-9,000 ft/canyons and dense forests
Razorback sucker		X	<6,000 ft/riverene and lacustrine areas, not in fast water
Southwestern willow flycatcher		X	<8,500 ft/cottonwood/willow and tamarisk vegetation along rivers and streams
Yuma clapper rail		X	<4,500 ft/fresh water and brackish marshes

Source: USFWS 2006

The Colorado River Multi-Species Conservation Program (MSCP) is a cooperative effort to address threatened and endangered species that may be affected by the operation and maintenance of the Colorado River from Lake Mead to the international border. Conservation actions implemented through the MSCP occur throughout the planning area on the Colorado River and on adjacent lands. The MSCP plan for the Lake Mead area includes conservation measures for two plants listed by the State of Nevada, for conservation of relict leopard frog, and for conservation of a number of riparian obligate species. In addition, razorback sucker larvae are collected from Lake Mead and raised to a size less vulnerable to predation prior to release back into the lake.

Lake Mohave functions as genetic refugia for razorback sucker. Under the MSCP, plan for the Lake

[2] An "endangered species" is defined by the USFWS as "an animal or plant species in danger of extinction throughout all or a significant portion of its range," while a "threatened species" is "an animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

Mohave area razorback sucker larvae are collected and reared prior to release back into that lake or elsewhere, including Lake Havasu. Suitable habitat within Havasu NWR adjacent to Topock Marsh is maintained for southwestern willow flycatcher and Yuma clapper rail. In addition, Beal Lake, just west of Topock Marsh, is managed as a refuge for native razorback sucker and bonytail chub. There is experimental planting to create cottonwood-willow habitat suitable for southwest willow flycatcher and other riparian obligate species on lands adjacent to Beal Lake.

Recreation Areas, Wildlife Refuges and Wilderness Areas

A significant portion of the Lake Mead National Recreation Area (NRA), created in 1964 and administered by the National Park Service, is located in the northwestern portion of the Upper Colorado River Planning Area. The NRA stretches from Davis Dam at Bullhead City in the Lake Mohave Basin to the western boundary of Grand Canyon National Park in Meadview Basin and includes Lake Mead, Lake Mohave, the Colorado River and adjacent areas. NRA lands also are located in Detrital Valley and Hualapai Valley Basins. The Peach Springs Basin contains a section of Grand Canyon National Park.

There are two National Wildlife Refuges (NWR) in the planning area, the Havasu NWR in the Lake Havasu Basin and the Bill Williams River NWR in the Bill Williams Basin. The Havasu NWR, managed by the USFWS, was established in 1941 at the time of construction of Parker Dam as a refuge for migratory birds and other wildlife. The refuge protects 30 river miles of the Colorado River from Needles, CA to Lake Havasu City, AZ and contains one of the last remaining natural stretches of the lower Colorado River through the 20-mile long Topock Gorge. A portion of the refuge in Arizona is designated as the Needles Peak Wilderness. The Bill Williams River NWR, located along the Bill Williams River at its confluence with Lake Havasu, includes lands originally set aside as Havasu NWR and additional lands purchased by USFWS since then. The refuge protects one of the last stands of natural cottonwood-willow habitat along the lower Colorado River (USFWS, 2002). The refuge provides habitat for at least two endangered species, the Yuma clapper rail and the southwestern willow flycatcher (NEMO, 2005).

Alamo Wildlife Area, managed by Arizona Game and Fish, is located at the confluence of the Big Sandy, Santa Maria, and Bill Williams Rivers and includes lands withdrawn and acquired by the U.S. Army Corps of Engineers for Alamo Lake at the time of construction of Alamo Dam in 1968. Arizona State Parks manages Alamo Lake State Park on the south shore of Alamo Lake.

The Bill Williams River Corridor Steering Committee coordinates activities regarding the operation of Alamo Dam and management of resources from Alamo Lake downstream along the Bill Williams River to Lake Havasu. Information can be found at http://billwilliamsriver.org/. In general, water is released in a manner that mimics natural flooding to promote establishment of native riparian woodland vegetation, including cottonwood and willow, and to ensure sufficient baseflow to support riparian vegetation between Alamo Dam and Lake Havasu.

A prominent feature of the planning area is the large number of Wilderness Areas administered by the Bureau of Land Management. These areas are designated under the 1964 Wilderness Act to preserve and protect the designated area in its natural condition. Designated areas, their size, basin location and a brief description are listed in Table 4.0-3. Wilderness areas represent about 6% of

the total planning area lands and almost 12% of the lands within the Bill Williams Basin.

Several "unique waters", designated by the Arizona Department of Environmental Quality (ADEQ) pursuant to A.A.C. R18-11-112, as having exceptional recreational or ecological significance and/or providing habitat for threatened or endangered species, have been identified in some of these wilderness areas. Designated unique waters include sections of Peoples Canyon, Francis Creek and Burro Creek in the Bill Williams Basin.

Table 4.0-3 BLM Wilderness Areas in the Upper Colorado River Planning Area

Wilderness Area	Acres	Basin	Description
Arrastra Mountain	129,800	Bill Williams	Includes portions of the Big Sandy and Santa Maria Rivers, and Peoples Canyon riparian area, classified as a unique water.
Aubrey Peak	15,400	Bill Williams	Mohave/Sonoran Desert transition zone, volcanic formations, caves and tinajas
Mt. Nutt	27,660	Lake Mohave, Sacramento Valley	Highest portions of the Black Mountains, steep canyons, bighorn sheep
Mt. Tipton	30,760	Detrital Valley, Hualapai Valley	Highest peaks in the Cerbat Mountains and Cerbat Pinnacles
Mt. Wilson	23,900	Detrital Valley	Most prominent range in Hoover Dam area, bighorn sheep
Rawhide Mountains	38,470	Bill Williams	8 miles of the Bill Williams River and gorge
Swansea	16,400	Bill Williams	Buckskin Mountains and 6 miles of Bill Williams River
Tres Alamos	8,300	Bill Williams	Colorful Tres Alamos monolith and Black Mountains
Upper Burro Creek	27,440	Bill Williams	Perennial, lower elevation stream, basalt mesas. Francis Creek, and Burro Creek from Francis Creek to Boulder Creek, are classified as unique waters.
Wabayuma Peak	40,000	Sacramento Valley	One of highest peaks in region, wide range of ecosystems
Warm Springs	112,400	Lake Mohave, Sacramento Valley	Black Mesa, canyons and springs
Total Acres	470,530		

Source: BLM 2006, A.A.C 18-11-112

4.0.5 Population

Census data for 2000 show about 153,800 residents in the Upper Colorado River Planning Area. Arizona Department of Economic Security (DES) population projections forecast that the planning area population will double by 2050, to about 303,500 residents. Historic, current and projected populations for each basin are shown in the basin cultural water demand tables. Projections may not accurately reflect the most recent proposed developments, which include large master-planned communities in the Detrital Valley and Hualapai Valley basins.

The most populous basins reported in the 2000 Census are the Lake Mohave (51,549), Lake Havasu (44,591), Hualapai Valley (31,543), and Sacramento Valley (16,276) basins. The remaining basins have populations of less than 5,000 residents. The 2000 Census population of the Fort Mojave Reservation was 773, with 1,353 residents on the entire Hualapai Indian Reservation.

Shown in Table 4.0-4 are incorporated and unincorporated communities in the planning area with 2000 Census populations greater than 1,000 and growth rates for two time periods. Only three incorporated communities exist within the planning area, Lake Havasu City, Bullhead City, and Kingman. Communities are listed from highest to lowest population according to the most recent reported year (2000 or 2005). Mohave County was the fastest growing county in Arizona between 1990 and 2000, growing at a rate of 65.8% during that period. The planning area population, which includes parts of other counties, grew by 62.6% during this time. Mohave County is the fourth most "urban" county in the state, with 75.3% of its residents residing in "urban clusters," defined by the U.S. Census Bureau as densely settled areas with a population of 2,500 to 49,999. There are no Census defined "urbanized areas" in the planning area, which are densely settled areas containing at least 50,000 people (U.S. Census, 2005). Communities with more than 1,000 residents grew at a rate of 58.3% compared to 9.9% outside these areas.

Population Growth and Water Use

Growing Smarter and Local Planning

The State has limited mechanisms to address the connections between land use, population growth and water supply. The Growing Smarter Plus Act of 2000 (Act) is a legislative attempt to link growth and water management planning. It requires counties with a population greater than 125,000 (2000 Census) to include a water resources element in their comprehensive plans. Both Mohave and Yavapai counties fit the population criteria. There is little population or water development within the Yavapai County section of the planning area. The Mohave County water resources element includes an overview of water resources, information on wells, surface water flows, water quality, Colorado River entitlement holders, water issues and projected water use.

The Act requires that 23 communities outside AMAs include a water resources element in their general plans. For the Upper Colorado River Planning Area these communities are: Bullhead City, Kingman and Lake Havasu City.

The Bullhead City water resource element focuses on Colorado River entitlements within its planning area and identifies as goals: 1) to acquire water resources to meet anticipated future needs and 2) to continue water conservation measures. The Kingman element discusses its groundwater

supplies in the Hualapai Valley and Sacramento Valley basins, future wellfield development and potential use of alternative supplies, including effluent. The Lake Havasu City General Plan includes policies to acquire additional water supplies and implement water conservation strategies to ensure that implementation of the general plan, which guides development, does not negatively impact Lake Havasu City's water resources. Water resource elements may contain useful information for planning and are listed in basin references in this volume.

Table 4.0-4 Communities in the Upper Colorado River Planning Area with a 2000 Census population greater than 1,000

Communities	Basin	1990 Census Pop.	2000 Census Pop.	Percent Change 1990-2000	2005 Pop. Estimate	Percent Change 2000-2005	Projected 2050 Pop.
Lake Havasu City	Lake Havasu	24,363	41,938	72.1	53,435	27.4	94,457
Bullhead City	Lake Mohave	21,951	33,769	53.8	38,210	13.1	71,423
Kingman	Sacramento Valley	12,722	20,069	57.8	25,860	28.8	38,737
New Kingman-Butler	Hualapai Valley	11,627	14,810	27.4	NA	---	39,033
Mohave Valley	Lake Mohave	6,962	13,694	9.7	NA	---	22,160
Golden Valley	Lake Mohave	2,619	4,515	7.2	NA	---	5,504
Desert Hills	Lake Havasu	1,700	2,183	28.4	NA	---	2,285
Dolan Springs	Detrital Valley	1,090	1,867	7.1	NA	---	2,054
Bagdad	Bill Williams	1,858	1,578	-15.1	NA	---	1,879
Total >1,000		84,892	134,423	58.3	NA	---	277,532
Other		9,722	19,381	9.9	NA	---	25,938
Total		**94,614**	**153,804**	**62.6**	NA	---	**303,470**

Source: DES, 2005: www.workforce.az.gov, U.S. Census Bureau, 2006
Notes: 2005 population estimates not available for unincorporated communities
NA = not available

Water System Plans and Annual Reports

Beginning in 2007, all community water systems in the state are required to submit Annual Water Use Reports and System Water Plans. The reports and plans are intended to reduce community water systems' vulnerability to drought, and to promote local water resource planning. The information will also allow the State to provide regional planning assistance.

The Annual Water Use Report includes information on water pumped or diverted, water received, water delivered to customers, and effluent used or received. The System Water Plan will be updated and submitted every five years. It consists of three components, a Water Supply Plan, a Drought Preparedness Plan and a Water Conservation Plan. Systems with populations of more than 1,850 were required to submit plans by January 1, 2007. Systems with populations smaller than 1,850 are required to submit plans by January 1, 2008. Plans have been submitted by most of the larger systems in the planning area and were used in the preparation of this document.

Water Adequacy Program

The Department's Water Adequacy Program also connects water supply and demand to growth to some extent but does not control growth. Developers of subdivisions outside of AMAs must obtain a determination of whether there is sufficient water of adequate quality available for 100 years. If the supply is inadequate, the developer may sell lots, but must disclose the condition of the water supply in promotional materials and sales documents. Subdivision adequacy determinations (Water Adequacy Reports), including the reason for the inadequate determination, are provided in the basin sections of this volume and are summarized for each basin in Table 4.0-5.

Table 4.0-5 Water Adequacy Determinations in the Upper Colorado River Planning Area as of 12/2006.

Basin	Number of Subdivisions	Number of Lots[1]	Adequate	Inadequate	Percent Inadequate
Big Sandy	4	≥608	UNK	608	UNK
Bill Williams	7	≥99	≥99	0	0
Detrital Valley	27	≥3994	0	≥3,994	100
Hualapai Valley	40	≥17,632	10,969	≥6,663	38
Lake Havasu	13	≥1,564	≥1,564	UNK	UNK
Lake Mohave	254	≥31,898	≥31,626	272	<1
Meadview	5	2,989	0	2,989	100
Peach Springs	none	none	none	none	none
Sacramento Valley	29	≥4,083	1,012	≥3,071	>75
TOTAL	**379**	**≥62,768**	**≥45,171**	**≥17,597**	**28**

Source: ADWR 2006b, ADWR 2006c
Notes:
[1] Data on number of lots are missing for some subdivisions, actual number is larger
UNK = Unknown

The service areas of eight water providers in the planning area have been designated as having an adequate water supply. If a subdivision is served by one of these designated water providers, a separate adequacy determination is not required. As of January 1, 2007 these designated providers and area served included:

- Cerbat Water Company (Cerbat Ranches, Hualapai Valley Basin)
- Golden Valley Water Improvement District (Golden Valley, Sacramento Valley Basin)
- Joshua Valley Utility Company (Meadview, Meadview Basin)
- City of Kingman (Hualapai Valley and Sacramento Valley Basins)
- Lake Havasu City (Lake Havasu Basin)
- Valley Pioneer Water Company (Golden Valley, Sacramento Valley Basin)
- City of Bullhead City (Arizona-American Water Works, Bermuda Water Company, North Mohave Valley Corporation; Lake Mohave Basin)
- Walnut Creek Water Company (Walnut Creek Estates, Sacramento Valley Basin)

As of February 2007, applications were pending to modify the designations of the City of Bullhead City and Golden Valley Water Improvement District. The current designation for the City of Bullhead City is pursuant to A.R.S. 45-108D, which allows designation of a city or town without it being a water provider if it has a Colorado River allocation and other conditions are met. Bullhead City is now seeking to become a water provider and wants to modify its designation to reflect that change. In addition, because of recent requests for service, the City of Kingman may need to modify its designation of water adequacy.

There is considerable development pressure occurring in the northwestern part of the planning area. This area is relatively near Las Vegas, NV, one of the fastest growing communities in the United States. The completion of a bridge across the Colorado River south of Hoover Dam, slated for 2010, will facilitate access to the area from Las Vegas. A type of adequacy application, not displayed in Table 4.0-5, is an Analysis of Adequate Water Supply (AAWS). This application typically is associated with large, master-planned communities. AAWS applications for two large developments in the planning area have been approved by the Department within the last nine months. The Ranch at White Hills, a 25,000 residential lot development in the Detrital Valley Basin was approved in June 2006 and a 23,000 residential lot development, Mardian Ranch in the Hualapai Valley Basin, was approved in January 2007. An additional 12 AAWS applications totaling more than 295,000 lots were pending review by the Department as of the end of February 2007. These pending applications include approximately 33,000 lots in the Detrital Valley Basin, approximately 17,000 lots in the Big Sandy Basin, and approximately 245,000 lots in the Hualapai Valley Basin. Information regarding the status of pending and approved applications is available at the Department's website.

4.0.6 Water Supply

Water supplies in the Upper Colorado River Planning Area include Colorado River water, other surface water, groundwater, and effluent. Colorado River water serves as the primary water supply in the Lake Havasu and Lake Mohave basins. It is also used to meet environmental water demands for the Havasu National Wildlife Refuge in the Sacramento Valley Basin. Elsewhere,

groundwater is the primary water supply. A discussion of Colorado River water entitlements and accounting is presented below. However, for the purpose of the Atlas, the subsequent individual basin discussions will report the use of Colorado River water as either groundwater, if it is pumped from a well within the hydraulically connected aquifer, or as surface water when it is directly diverted from the river.

Colorado River Water

Decree Accounting

The right or authorization to beneficially use Colorado River water is defined as an entitlement. Entitlements held by Colorado River water users are created by decree of the United States Supreme court in *Arizona v. California et al.* (Decree), through a contract with the Secretary of the Interior (Secretary) under Section 5 of the Boulder Canyon Project Act (BCPA) of December 21, 1928, or by Secretarial Reservation.

Table 4.0-6 shows the annual total amount of Colorado River water that was consumptively used for each category of water use within each basin in the planning area based on an accounting system established by Decree. Article V of the Decree directs the U.S. Bureau of Reclamation (Reclamation) to prepare an annual report of diversions from the mainstream, return flow of water to the mainstream that makes water available for downstream consumptive use in the U.S. or in satisfaction of the Mexican Treaty obligation, and the consumptive use of such water. The Article V report lists diversions and return flow separately by diverter, point of diversion and state, for each of the lower basin states.

According to the Article V report, consumptive use of Colorado River water in the planning area for agricultural, municipal, industrial and environmental purposes averaged 126,167 acre-feet annually for the 2001-2003 time period. The table shows the quantities of water diverted by surface water diversions, in-river pumps, or pumped from wells assumed to be located within the hydraulically connected aquifer of the Colorado River. When determining consumptive water use, the Article V accounting system considers measured return flow and estimates of unmeasured return flows to the mainstream.

Reclamation has made a preliminary delineation of the lateral and vertical extent of the Colorado River aquifer to provide a basis for accounting of withdrawals against river water allocations. On August 18, 2006, Reclamation initiated a rulemaking process for *Regulating Non-Contract Use of Colorado River Water in the Lower Basin* (71 Federal Register 47763 et seq.) to prevent non-contract Colorado River water use from depleting the river and taking water from holders of Colorado River water entitlements. Reclamation's most current assessment indicates that most existing non-contract water use results from water withdrawn from wells located within the hydraulically connected aquifer of the Colorado River or from river pumps.

Because of the complexity of the accounting system and its unique methodology, the cultural water demand tables in sections 4.2, 4.3, 4.5, 4.6 and 4.9 (those basins that utilize this supply), reflect the amount of water pumped from wells and diverted from streams. The tables do not attempt to distinguish whether the water is used pursuant to the entitlement system.

Table 4.0-6 *Arizona v. California* Decree accounting of the consumptive use of Colorado River water in the Upper Colorado River Planning area (in acre-feet/year)

Basin/Year [1]	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-03	Current Entitlement
Bill Williams								
Agricultural	None							
Industrial	None							
Municipal	0	0	0	0	20	18	26	84
Environmental	None							
Detrital								
Agricultural	None							
Industrial	None							
Municipal	0	0	0	0	116	146	126	Unspecified
Environmental	None							
Lake Havasu								
Agricultural	None							
Industrial	None							
Municipal	5,554	8,075	8,872	11,604	13,376	15,053	14,619	29,254
Environmental [2]	14,300	14,064	7,828	15,456	15,927	12,561	7,577	16,317
Lake Mohave								
Agricultural	20,209	47,172	73,885	83,109	96,123	107,700	79,039	144,535
Industrial	216	220	158	103	80	0	3,600[3]	175
Municipal	295	298	581	6,062	7,857	9,669	9,328	44,192
Environmental [2]	14,300	14,064	7,828	15,456	15,927	12,561	7,577	16,317
Sacramento								
Agricultural	None							
Industrial	None							
Municipal	None							
Environmental [2]	8,066	7,934	4,416	8,719	8,984	7,086	4,274	9,205
TOTAL	62,939	91,826	103,567	140,507	158,409	164,793	126,167	260,079
Central Arizona Project [4]	0	0	33,502	499,917	717,514	1,330,109	1,596,626	Unspecified

Source: BOR 2007a

Notes:

[1] It should be noted that the reported consumptive use for individual users may not cover an entire 5 year period, the average is based on the years of record.

[2] The Havasu National Wildlife Refuge spans an area that is located in the Lake Mohave, Lake Havasu, and Sacramento Valley basins. The consumptive use has been prorated based on the percentage of the Refuge land area in each basin.

3 The Fort Mojave entitlement does not contain a division between agricultural and non-agricultural use. The amount shown here is an average of approximately 3,600 af per year used by the Fort Mojave Reservation for operation of the South Point Power Plant between mid 2001-2003. This amount has been subtracted from the total agricultural use for 2001-2003.

4 The Central Arizona Project diverts water out of Lake Havasu (located in the Bill Williams Basin) for multiple uses in Maricopa, Pinal, and Pima counties.

Entitlement Priority Levels

Rights to Colorado River water include the following several priority levels:

a. 1st Priority: Satisfaction of Present Perfected Rights as defined in the *Arizona v. California* decree
b. 2nd Priority: Satisfaction of Secretarial Reservations and Perfected Rights established prior to September 30, 1968
c. 3rd Priority: Satisfaction of entitlements pursuant to contracts between the United States and water users in Arizona executed on or before September 30, 1968 (2nd and 3rd priority are coequal)
d. 4th Priority: i) Contracts, Secretarial Reservations and other arrangements between the U.S. and water users in Arizona entered into after September 30, 1968, for a total quantity not to exceed 164,652 acre-feet of diversions annually and ii) contract No. 14-06-W-245, dated December 15, 1972, as amended, between the United States and the Central Arizona Project (CAP). Entitlements having a 4th priority as described in (i) and (ii) are coequal.
e. 5th Priority: Unused entitlement
f. 6th Priority: Surplus water

In general, the lower priority entitlements will be the first to be impacted when the Secretary declares a shortage on the Colorado River system. Within the planning area, entitlement holders with a first priority or present perfected rights include the Fort Mojave Indian Reservation and several private entities within the Mohave Valley Irrigation and Drainage District. Second and third entitlement holders (which are coequal during a shortage), include Havasu National Wildlife Refuge, Bureau of Reclamation (Davis Dam), and the National Park Service. Fourth priority entities include Arizona-American Water Company (Lake Havasu), Bullhead City, Golden Shores Water Conservation District, Lake Havasu City, Mohave Water Conservation District, Mohave Valley Irrigation and Drainage District, and the Mohave County Water Authority. Lake Havasu City and the Mohave County Water Authority also have fifth and sixth priority entitlements.

Mohave County Water Authority

The Mohave County Water Authority (MCWA) was organized pursuant to A.R.S.§ 45-2201 primarily for the purpose of acquiring the city of Kingman's unused 18,500 acre-feet entitlement and making it available to other authority members for municipal and industrial water uses. Authority members include Arizona-American Water Company, Bullhead City, Golden Shores Water Conservation District, Kingman, Lake Havasu City, Mohave County, Mohave Valley Irrigation and Drainage District and Mohave Water Conservation District. As well as providing other services and functions, the Authority can acquire additional water supplies, including effluent, and it may store, recharge and recover these supplies for the benefit of Mohave County water users. The Authority can also assist members with the development and operation of water diversion, conveyance, treatment, storage and recharge facilities and the development of augmentation and conservation programs.

Arizona Water Banking Authority

The Arizona Water Banking Authority (AWBA) was created in 1996 to protect Arizona's Colorado River interests and to provide for interstate water banking opportunities. Among its statutory authorities is the requirement to reserve a reasonable number of long-term storage credits

developed with general fund appropriations for the benefit of Municipal and Industrial (M&I) water users located near the Colorado River (on-river users), during times of shortage. Fourth priority Colorado River M&I water users have no alternate water supply during times of shortage. Regardless of whether water is diverted from the Colorado River water or pumped from within the hydraulically connected river aquifer, the limit of an entity's water right is its Colorado River entitlement. On January 1, 1998, the AWBA adopted 420,000 acre-feet as the reasonable number of long-term storage credits for on-river M&I "firming." Contractors may recover this firmed or stored water in times of shortage. (See Volume 1, Appendix A for more information on the AWBA).

The manner in which the general fund credits would be reserved, and then recovered and distributed during a shortage, has long been an issue of concern to the on-river users. In recognition of the concerns, the AWBA and the MCWA entered into the Agreement to Firm Future Supplies (Agreement to Firm). The Agreement to Firm recognizes that the MCWA can enter into subcontracts with on-river M&I water users having the same priority as the CAP. These are the same water users for whom the AWBA must firm M&I supplies. Upon execution of the subcontracts and payment of the appropriate fees, the AWBA would reserve the appropriate quantity of long-term storage credits as described in the Agreement to Firm.

The parties executed the Agreement to Firm on February 4, 2005. The MCWA offered all entities in Mohave County the option to participate in the Agreement. Subcontract entities included in the Agreement to Firm are Arizona State Parks, Bullhead City, Lake Havasu City, and Mohave Water Conservation District. Pursuant to the Agreement to Firm, 230,280 acre-feet of the current 396,499 acre-feet of credits in the General Fund Account were transferred to a sub-account in MCWA's name. The remaining credits in the General Fund Account could still be available to firm on-river supplies.

Drought

The Colorado River reservoirs are operated in accordance with the Colorado River Basin Project Act of 1968 (P.L. 90-537). Hydrologic conditions in the Colorado River Basin affect reservoir operation. The Colorado River Basin experienced five consecutive years of extreme drought during water years 2000-2004 and, while there was above average inflow to Lake Powell and record-breaking tributary flows in the Lower Colorado Basin in 2005, there was below average streamflow again in 2006 (BOR, 2006a). During this period, storage in Colorado River reservoirs dropped from near capacity to 60 percent of capacity by the end of 2006. Reclamation lacks specific operation guidelines to address the operation of Lake Mead and Lake Powell during drought. To address this situation, in February, 2007, Reclamation released a draft environmental impact statement on proposed adoption of specific interim guidelines for Lower Basin shortages and coordinated operation of the two reservoirs. One of the purposes of the proposed action is to provide greater predictability regarding the amount of annual water deliveries to mainstream Colorado River water users in the Lower Division states (BOR, 2007b). The effect of drought and other hydrologic conditions on water levels in Lake Mead is shown in Figure 4.0-8. Lowering water levels have resulted in closure and relocation of boat marinas at Lake Mead.

Figure 4.0-8 Lake Mead end of month elevation 1980-2006

Surface Water

Surface water demand was about 66,300 acre-feet in 2003. Surface water is the primary water supply in the Lake Mohave Basin (65,100 acre-feet/year) where it is the principal supply for agricultural and industrial use. About 500 acre-feet of surface water from springs near Bagdad in the Bill Williams Basin provide a municipal and industrial supply for the town of Bagdad and the Bagdad mine. Small volumes of surface water are used in the Detrital Valley and Lake Havasu basins. Surface water may be used elsewhere but records are not available. There are few springs in proximity to water demand centers and, with the exception of the Colorado River, perennial streams are located only in the Bill Williams and Big Sandy basins. The location of surface water resources are shown on surface water condition maps, maps showing perennial and intermittent streams and major springs for each basin, and in basin tables containing data on streamflow, flood ALERT equipment, reservoirs, stockponds and springs in the Water Resource Characteristics sections for each basin.

Groundwater

Groundwater pumpage was about 104,150 acre-feet in 2003. Groundwater is found at varying depths in the planning area, generally in the 200 to 600-foot range although water levels of more than 1,000 feet below land surface are found in the Hualapai Valley, Peach Springs and northern Sacramento Valley basins. Groundwater is pumped from basin fill material in most basins with the exception of the Meadview and Lake Mohave basins. Recent stream alluvium also is a potentially important aquifer in the Big Sandy, Bill Williams, Detrital Valley and Lake Mohave basins. Sedimentary rocks are principal aquifers in five north and northeastern basins including the Big Sandy, Detrital Valley, Hualapai Valley, Peach Springs and Meadview. In the Bill Williams and

Sacramento Valley basins, aquifers in volcanic rock also are utilized. Groundwater is limited due to water quality and quantity issues at the town of Chloride, north of Kingman in the Sacramento Valley Basin.

Estimated volumes of groundwater in storage may be limited in some basins and estimates may range significantly depending on the data source. The USGS, in conjunction with the Department, is currently conducting an investigation of groundwater conditions in the Detrital Valley, Hualapai Valley and Sacramento Valley basins in light of proposed developments. The Department has recently released a revised estimate of the volume of groundwater in storage in the Detrital Valley Basin (ADWR, 2006). Groundwater storage estimates for these basins are: 1.4 to 3.7 maf in the Detrital Valley, 5 to 5.3 maf in the Hualapai Valley, and 7 to 8.3 maf in the Sacramento Valley, to a depth of 1,200 feet.

In order to better understand the water supply situation in areas of the state where data are lacking, the Department has established automated groundwater monitoring sites that record water levels in wells. This information is available through an interactive map on the Department's website to allow access to local information for planning, drought mitigation, and other purposes (http://arcims.azwater.gov/website/AutomatedSites/AutoSites_disclaimer.htm). The location criteria used to site these devices were based on areas of growth, subsidence, type of land use, proximity to river/stream channels, proximity to water contamination sites or areas affected by drought. Figure 1-18 of Atlas Volume 1 shows the location of automatic water-level recording sites as of 2005. At that time there were three sites, one of which was a USGS site, in the planning area. There currently are four automated Department-operated sites in the planning area for record water levels four times daily.

Index well hydrographs, which display long-term water level behavior in 61 planning area index wells that are measured annually, also are available on the Department's website through an interactive map (http://arcims.azwater.gov/website/IndexWell/IndexWell_disclaimer.htm). Information on major aquifers, well yields, estimated natural recharge, estimated water in storage, aquifer flow direction, and water level changes are found in groundwater data tables, groundwater conditions maps, hydrographs and well yield maps for each basin in the Water Resource Characteristics sections.

Effluent

Effluent is a potential water supply at locations throughout the planning area, but is currently utilized in only the Lake Havasu and Lake Mohave basins where about 3,200 acre-feet/year are used for turf irrigation. Approximately 2,600 acre-feet of effluent was produced in the Lake Havasu Basin in 2006 and more than 2,300 acre-feet was used. Lake Havasu City delivers about 1,300 acre-feet of effluent to end users in the City and approximately 1,000 acre-feet to end users outside of the City area. Lake Havasu City is evaluating new sources of effluent demand as well as effluent recharge. Approximately 3,000 acre-feet of effluent is produced in the Lake Mohave Basin each year. Within the basin, Bullhead City annually delivers about 500 acre-feet of effluent and Arizona-American Water Company delivers about 300 acre-feet.

The Kingman-Hilltop Wastewater Treatment Plant, located in the Hualapai Valley Basin, generates

about 1,800 acre-feet of effluent per year which is currently disposed in a wetland and evaporation ponds. The treatment system in the Peach Springs Basin in the community of Peach Springs is essentially a sewer collection system with secondary treatment and disposal in evaporation ponds and unlined impoundments. There are four wastewater treatment plants in the Sacramento Valley Basin, one in Kingman, one at the Griffith power plant and two in the vicinity of Franconia, located about midway between Topock and Yucca. Information is available on only two plants in the basin, which produce a total of about 400 acre-feet of effluent, all of which is disposed of in evaporation ponds or in a watercourse.

No wastewater treatment facilities were identified by the Department in the Big Sandy, Bill Williams or Meadview basins. A facility exists at Temple Bar in the Detrital Valley Basin but information on volume treated and disposal method was not available to the Department.

Contamination Sites

Sites of environmental contamination may impact the availability of water supplies. An inventory of Department of Defense, Superfund (Environmental Protection Agency designated sites), Resource Conservation and Recovery Act (RCRA), Water Quality Assurance Revolving Fund (WQARF, state designated sites), Voluntary Remediation Program (VRP), and Leaking Underground Storage Tank (LUST) sites was conducted for the planning area. Of these various types of sites, only LUST, VRP and RCRA sites are found in the planning area. The location of all contamination sites is shown on Figure 4.0-9.

There are five active VRP sites in the planning area, primarily associated with crude oil contamination of soil. Table 4.0-7 lists the VRP sites, their contaminants and affected media, and respective basins.

Table 4.0-7 Active contamination sites in the Upper Colorado River Planning Area

SITE NAME	MEDIA AFFECTED AND CONTAMINANT	GROUNDWATER BASIN
Resource Conservation and Recovery Act (RCRA) Sites		
McCulloch Corporation	Soil and groundwater - chromium, other metals	Lake Havasu
Snavely Lease	Soil	Sacramento Valley
Voluntary Remediation Sites		
Inactive Bruce Mine	Groundwater-copper, zinc, pH, other metals or organic contaminants	Bill Williams
Juniper Pump Station	Soil-crude oil	Big Sandy
New Kingman Pump Station	Soil-crude oil	Big Sandy
Oatman Pump Station	Soil-crude oil	Lake Mohave
Old Kingman Pump Station	Soil-crude oil	Sacramento Valley

Sources: ADEQ 2002, ADEQ 2006a, ADEQ 2006b

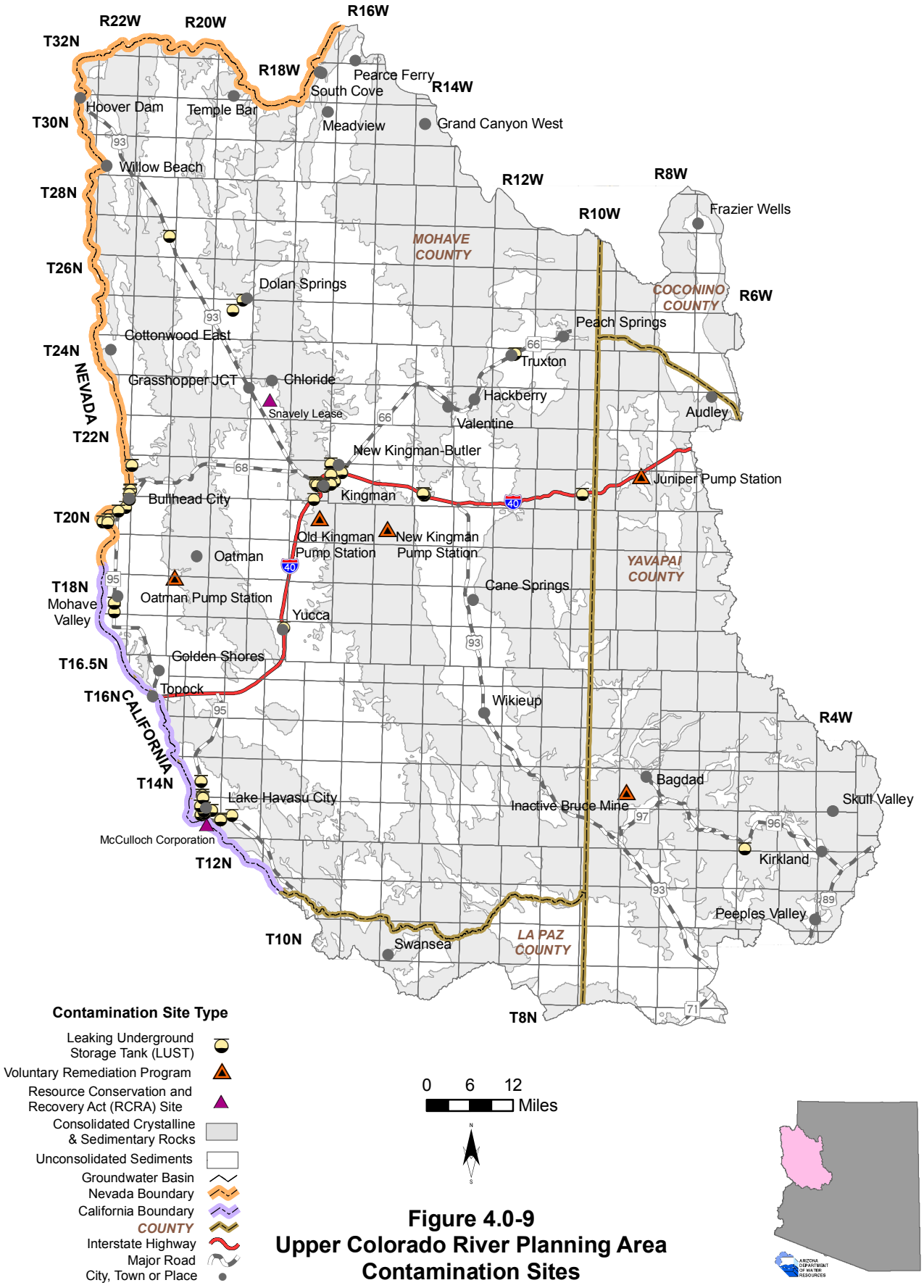


Figure 4.0-9
Upper Colorado River Planning Area
Contamination Sites

The VRP is a state-administered and -funded voluntary cleanup program. Any site that has soil and/or groundwater contamination, provided that the site is not subject to an enforcement action by another remediation program, is eligible to participate. To encourage participation, ADEQ provides an expedited process and a single point of contact for projects that involve more than one program (Environmental Law Institute, 2002).

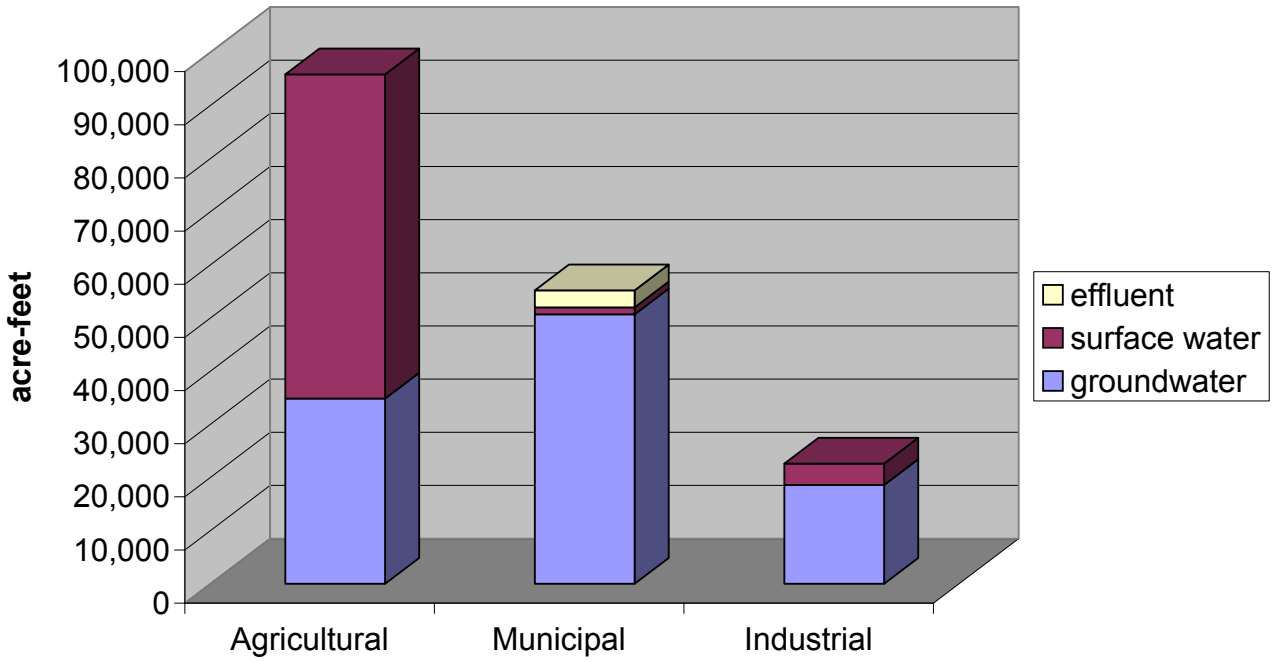
As of 2002, there were two federal RCRA sites in the planning area. (See Table 4.0-7) The program regulates the management of hazardous waste handlers which includes generators, transporters and facilities for treatment, storage and disposal. (ADEQ, 2002)

There are 153 active LUST sites in the planning area. There are 60 sites in the Kingman area in the Sacramento Valley Basin, 30 sites in and around Bullhead City in the Lake Mohave Basin, and 47 sites in the vicinity of Lake Havasu City in the Lake Havasu Basin.

4.0.7 Cultural Water Demand

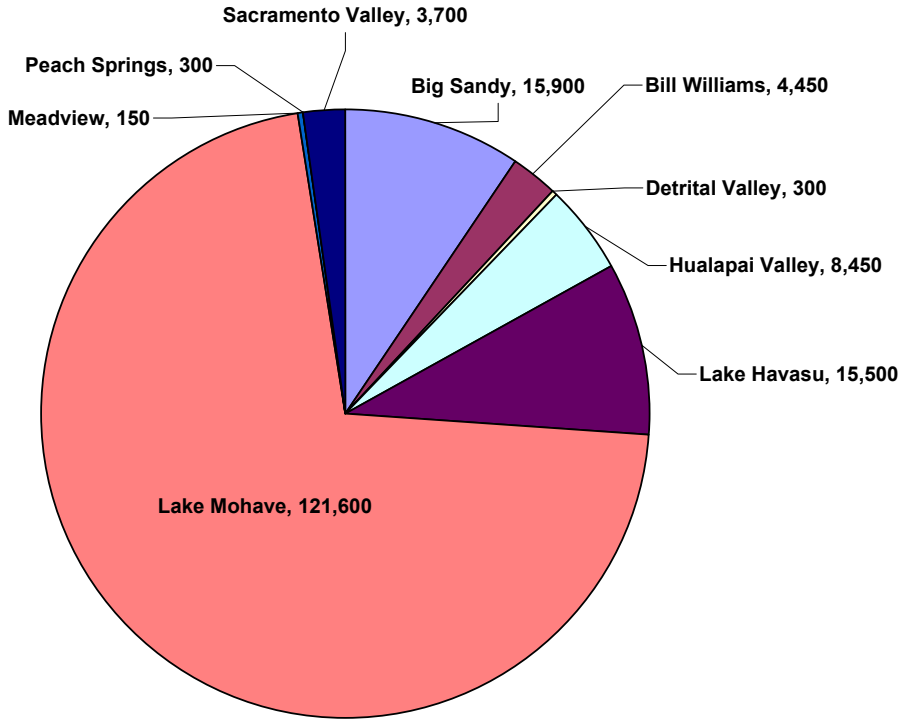
Total cultural water demand in the Upper Colorado River Planning Area averaged approximately 173,650 acre-feet per year in the period from 2001-2003. As shown in Figure 4.0-10, agricultural demand is the largest use sector with approximately 95,850 acre-feet of demand per year due almost entirely to farming in the Lake Mohave Basin. Municipal demand is the next largest water demand sector at approximately 55,200 acre-feet per year of primarily groundwater. About 1,300 acre-feet of surface water and about 3,200 acre-feet of effluent are also used for municipal

Figure 4.0-10 Upper Colorado River Planning Area cultural water demand by sector, 2001-2003 in acre-feet



purposes. Industrial demand, primarily for mining, is about 22,600 acre-feet per year. Of this, about 4,000 acre-feet of surface water is used. Cultural demand volumes vary substantially between the planning area basins and range from about 150 acre-feet a year in the Meadview Basin to about 121,600 acre-feet a year in the Lake Mohave Basin (see Figure 4.0-11).

Figure 4.0-11 Average total basin water demand per year in acre-feet, 2001-2003



Tribal Water Demand

The Fort Mojave Indian reservation includes lands in Arizona, Nevada and California but almost 70% of its landbase (23,500 acres), is located within Arizona in the Lake Mohave Basin. The Tribal headquarters are located in Needles, CA. In Arizona, the tribal population is approximately 800 and the primary water demand is farming. A small casino, with associated services is located in Mohave Valley while a large hotel/casino and golf course are located in Laughlin, NV. The Fort Mojave Tribal Utilities Authority serves about 850 customers in parts of Mohave Valley. The Bermuda Water Company apparently provides service to parts of Fort Mojave. In 2005, the tribal utility pumped about 260 acre-feet of groundwater (ACC, 2005). In 1999, the tribe entered into an agreement to allow construction of a gas-fired power plant on the reservation. The South Point Energy Center came on line in 2001 and was the first "merchant plant" built by an independent power company on tribal land (Calpine, 2001). All power generated is sold on the open market. Fort Mojave receives electricity generated at Parker Dam. The plant is designed to capture waste heat to generate a second phase of electricity, making it 40% more efficient than older natural gas plants. Water use by the plant is estimated at 4,000 acre-feet per year of surface water (BIA, 1998).

The Hualapai Indian Reservation encompasses about 552,800 acres in the planning area, primarily in the Peach Springs Basin. There also are small tracts of tribal lands in the Big Sandy, Hualapai Valley and Meadview basins. The reservation, created in 1883, has a current population of about 1,500. Peach Springs is the tribal capital. Tribal water use is estimated to be less than 300 acre-feet a year. The tribal economy is based on cattle ranching, tourism, timber sales and big game hunting. The Hualapai Department of Public Works operates water and sewer systems in Peach Springs. The Hualapai Water Resource Program develops non-community water sources and is responsible for a wetland and water quality monitoring program. The Range Water Program performs pipeline maintenance to cattle districts. (Hualapai Tribe, 2007)

The Hualapai Nation operates a tourist development at Grand Canyon West where a recently completed glass walkway, "Skywalk" extends 70 feet beyond the canyon edge almost a mile above the Colorado River. Water is an issue at the site and is currently trucked in. The tribe anticipates that Skywalk will promote further development at the site, requiring a local source of water (Cart, 2007). The tribe has considered drilling a local well, extending a water pipeline 26 miles from wells on the west side of the Reservation, or pumping water to the rim from the Colorado River. An exploratory well drilled near Grand Canyon West located water at more than 2,600 feet with an estimated flow of just 12 gpm (Hualapai Tribe, 2007). While the U.S. asserted tribal claims to the Colorado River in *Arizona v. California*, the Court only decided the claims of those tribes below Hoover Dam. There presently is no court action pending to adjudicate any Hualapai claims.

Municipal Demand

Municipal demand is about 55,200 acre-feet/year; 32% of the total cultural water demand. Municipal water demand is summarized by groundwater basin and water supply in Table 4.0-8. Water pumped from wells is the primary water supply for municipal use throughout the planning area as reflected in the cultural water demand tables for each basin. Approximately 50,700 acre-feet of groundwater was used in the planning area c. 2003. The largest volume of municipal groundwater use is in the Lake Mohave Basin with almost 24,000 acre-feet/year of demand-almost half of the total groundwater use. About 1,300 acre feet/year of surface water is used. The town

Table 4.0-8 Municipal water demand in the Upper Colorado River Planning Area (c. 2003)

Basin	Groundwater	Surface Water	Effluent[1]
Big Sandy	<300	0	0
Bill Williams	600	500	0
Detrital Valley	<300	<300	0
Hualapai Valley[2]	8,300	0	0
Lake Havasu	15,200	<300	2,357
Lake Mohave	24,000	500	842
Meadview	<300	0	0
Peach Springs	<300	0	0
Sacramento Valley	2,000	0	0
Total Municipal	50,700	1,300	3,199

Sources: USGS 2005, ADWR 2007, Malcolm Pirnie, Inc 2006, BOR 2006a, Lake Havasu City 2006
Notes:
[1] Effluent figures are for golf course and other turf irrigation in 2006
[2] The City of Kingman in the Sacramento Valley Basin obtains most of its water from well fields in the Hualapai Valley Basin

of Bagdad in the Bill Williams Basin uses about 500 acre-feet of surface water diverted from springs as its primary municipal supply. About 3,200 acre-feet of effluent is used annually for turf irrigation.

Principal municipal demand centers are Lake Havasu City, Bullhead City, and the Kingman area. There is little population or municipal demand in a number of basins in the planning area including the Big Sandy, Detrital Valley, Meadview and Peach Springs basins. Municipal demand on the Fort Mojave and Hualapai reservations is estimated at less than 300 acre-feet/year.

Only nine water providers in the planning area served 450 acre-feet of water or more in 2000 or 2003. These providers and their demand in 1991, 2000 and 2003 are shown in Table 4.0-9. Municipal gallon per capita per day (gpcd) rates in 2004/2005, which include golf course demand and lost water but not effluent, are estimated to be about 250 gpcd in Lake Havasu City, 300 gpcd in Bullhead City, and 193 gpcd in Kingman. Municipal utilities serve Lake Havasu City and the City of Kingman while other communities, including Bullhead City, are served by private water companies. Bullhead City is served by Arizona-American Water Company, Bermuda Water Company and North Mohave Valley Water Company and is intending to become a municipal water provider (BOR, 2006b). Municipal water utilities have more flexible water rate-setting ability than private water companies, which are regulated by the Arizona Corporation Commission. In addition, municipal utilities have the authority to enact water conservation ordinances. These authorities may enable municipal utilities to better manage water resources within water service areas. Water provider issues are discussed in section 4.0.8.

Table 4.0-9 Water Providers serving 450 acre-feet or more of water per year in 2000 or 2003, excluding effluent, in the Upper Colorado River Planning Area

Water Provider	1991 (acre-feet)	2000 (acre-feet)	2003 (acre-feet)
Bill Williams			
Phelps Dodge Bagdad, Inc, Utilties Dept.	871	749	732
Lake Havasu			
Lake Havasu City	11,961	14,630	15,660
Willow Valley Water (Mohave Valley)	542	455	414
Lake Mohave			
Bermuda Water Company (Bullhead City)	915	951	3,040
Arizona American Water (Bullhead City)	4,012	6,220	7,420
Golden Shores Water Company	353	452	550
North Mohave Valley Water (Bullhead City)	269	642	721
Sacramento Valley			
City of Kingman	5,950	7,294	8,662
Valley Pioneers Water Company	316	500	526

Sources: ADWR 1994b, ADWR 2004, ADWR 2005c, ADWR 2007
Notes:
Demand for the Town of Bagdad may include some industrial demand by the Bagdad Mine.

With the exception of three golf courses, all golf courses in the planning area are served from a municipal water supply, which may include effluent. All golf courses are shown in Table 4.0-10 with estimated demand and source of water. Golf courses that irrigate with water pumped from

facility wells are considered "industrial" golf courses and this use is accounted for as an industrial demand. Demand was not reported for a number of golf courses and in those cases estimates are based on turf water needs, elevation and duration of the irrigation season. Most golf courses are located in the Lake Havasu or Lake Mohave basins. There are two golf courses in the Kingman area in the Hualapai Valley Basin, and one in Bagdad in the Bill Williams Basin.

Table 4.0-10 Golf course demand in the Upper Colorado River Planning Area (c. 2006)

Facility	Basin	# of Holes	Demand (acre-feet)	Water Supply
Mesa View Golf Club	Bill Williams	9	211	Groundwater
Cerbat Cliffs Golf Course	Hualapai Valley	18	423	Groundwater
Valle Vista Country Club	Hualapai Valley	18	423	Groundwater
Refuge Golf Course	Lake Havasu	18	441	Effluent
Bridgewater Link/Queens Bay	Lake Havasu	9	220	Groundwater
London Bridge Golf Course	Lake Havasu	36	1,288	Effluent
Nautical/ Havasu Island Inn Golf Club	Lake Havasu	18	560	Effluent
Chaparral Country Club	Lake Mohave	9	220	Groundwater/Effluent
Desert Lakes Golf Club*	Lake Mohave	18	441	Groundwater/Effluent
El Rio Country Club*	Lake Mohave	18	441	Groundwater
Laughlin Ranch	Lake Mohave	18	425	Effluent
Riverview Golf Club*	Lake Mohave	9	220	Groundwater/Effluent
Total Demand			**5,313**	

Source: ADWR 2005b, BOR 2006a, Lake Havasu City 2006
Notes:
* These golf courses are served by their own wells and considered to be industrial users

Fifty-four percent of the golf course demand in the planning area is met with effluent. Effluent is utilized in Bullhead City, Lake Havasu City and in Mohave Valley. In the Lake Havasu Basin, almost 2,300 acre-feet of effluent was used in 2006 to irrigate three facilities that use 100% effluent: the Refuge Golf Course, London Bridge Golf Course, and Nautical/Havasu Island Inn Golf Club. In addition, about 68 acre-feet of effluent was used for other turf irrigation. This total volume is almost all the effluent produced in the basin. In the Lake Mohave Basin, about 840 acre-feet of effluent is used to irrigate four golf courses and one park. Bullhead City delivers about 600 acre-feet of effluent per year to Chaparral Country Club, Laughlin Ranch, and Rotary Park. Arizona-American Water Company delivers about 170 acre-feet of effluent per year to the Riverview Golf Course and about 130 acre-feet to the Desert Lakes Golf Course in Mohave Valley. Both courses are defined as industrial facilities that also use groundwater. It is anticipated that effluent use for turf irrigation will increase in the planning area.

Agricultural Demand

Agricultural demand is about 95,850 acre-feet/year; 55% of the total cultural water demand. Ninety-six percent of the agricultural demand occurs in the Lake Mohave Basin where principal crops include cotton, alfalfa, hay and wheat. Relatively small amounts of agricultural water demand are reported in the Big Sandy and Bill Williams basins. Surface water and groundwater use for agriculture in selected years for the entire planning area is shown in Table 4.0-11. As shown, total agricultural demand declined by over 12,000 acre-feet between 1991 and 2003. About 64% of the demand was met with surface water in 2003.

In the Lake Mohave Basin, agricultural irrigation occurs in the Mohave Valley on the Fort Mojave

Indian Reservation and on private lands located within the Mohave Valley Irrigation and Drainage District (MVIDD). In the southern end of the valley, tribal and district lands are interspersed in a checkerboard pattern. About 15,000 acres of reservation lands were recently under cultivation (ITCA, 2003), which may include non-Indian agricultural lessees. There are a total of about 31,500 acres within the MVIDD boundaries, of which about 3,800 acres are reported in cultivation. MVIDD does not divert or deliver water to its water users. District farmers operate and maintain their own production wells, pumps and distribution systems (ADWR, 1998).

Table 4.0-11 Agricultural demand in the Upper Colorado River Planning Area

	1991	2000	2003
	Water Use (acre-feet)		
Surface Water	56,600	68,100	61,000
Groundwater	51,550	38,850	34,850
TOTAL	108,150	106,950	95,850

Source: USGS 2005b, ADWR 2005d

Agricultural demand in the Lake Mohave Basin has increased substantially since the early 1970s when less than 20,000 acre-feet/year was used. Since 1990, annual agricultural demand has remained relatively constant, with up to 102,600 acre-feet/year used on average during the 1996-2000 time period. The increase is primarily due to Fort Mojave Indian agricultural water use. It is estimated that approximately 60-65% of the total current irrigation demand is attributable to tribal irrigation.

In the Big Sandy and Bill Williams basins irrigation is primarily for pasture. Irrigation in the Big Sandy Basin has been estimated at less than 300 acre-feet of groundwater per year since 1991, consisting of small pasture in the vicinity of the Big Sandy River. In the Bill Williams Basin, irrigation has declined from an average of 15,600 acre-feet per year during the 1991-1995 period to just 3,200 acre-feet per year from 2001-2003. This decline is primarily a result of cessation of farming at Planet Ranch, downstream from Alamo Dam, where flooding in 1993 washed out much of the irrigation infrastructure. Reportedly, only one cotton farm remains along the Bill Williams River below Alamo Dam. Most of the other remaining agricultural lands are located in the vicinity of Kirkland and Skull Valley (see Figure 4.2-10).

Industrial Demand

Annual industrial demand is approximately 22,600 acre-feet; 13% of the total cultural water demand. Industrial water demand in the planning area includes mining, electrical power generation, dairy/feedlot and golf course irrigation served by a facility water system. These use categories served by a municipal water system are accounted for as municipal demand. Industrial demand is summarized in Table 4.0-12 for selected years.

Mining is the largest industrial user in the planning area, primarily due to activities at the Phelps Dodge Bagdad Mine in the Bill Williams Basin. Most of the water used at the mine is apparently pumped from a series of wells along a 10-mile reach of the Big Sandy River north of Wikieup in the Big Sandy Basin, and delivered via pipeline to the mine site. A small volume of surface water (probably <300 acre-feet/year) from Francis Creek springs and wells in the vicinity of Bagdad

may also be used at the mine site although it is believed these sources primarily provide water for potable use in the company town of Bagdad. The volume of water used at the mine is proprietary and recent estimates were based on reported copper production and known processing methods.

Table 4.0-12 Industrial demand in selected years in the Upper Colorado River Planning Area

	1991	2000	2003
Type	**Water Use (acre-feet)**		
Mining Total	**16,673**	**19,287**	**16,568**
Big Sandy			
Groundwater	16,000	18,291	15,717
Bill Willams			
Groundwater	<300	<300	<300
Hualapai Valley			
Groundwater	<300	<300	<300
Lake Havasu			
Groundwater	9	118	66
Lake Mohave			
Groundwater	64	78	89
Peach Springs			
Groundwater	<300	<300	<300
Sacramento Valley			
Groundwater	<300	350	246
Power Plant Total	**0**	**0**	**5,600**
Lake Mohave			
Surface Water	0	0	4,000
Sacramento Valley			
Groundwater	0	0	1,600
Golf Course Total	**527**	**356**	**356**
Lake Mohave [1]			
Groundwater	527	356	356
Dairy/Feedlot Total	**76**	**76**	**76**
Sacramento Valley			
Groundwater	76	76	76

Source: ADEQ 2005, ADMMR 2005, ADWR 1994b, ADWR 2005b, ADWR 2007, BIA 1998,USGS 2005b

Notes:

[1] Two golf courses also receive effluent, see Table 4.0.9 for more information.

Claims were first staked at the Bagdad Mine property in 1882 with open pit mining beginning in 1945. Historically, mining operations were relatively small-scale due to the low grade copper ore. However, advances in ore processing have resulted in increased copper production at the site. Water use has increased from approximately 2,000 acre-feet/year in the early 1970s to an estimated 15,600 acre-feet/year on average. The mine consists of a porphyry copper open-pit copper mine and concentrator. Molybdenum is a by-product of the mining operation. The site is recognized as the world's first commercial-scale concentrate leach processing facility (beginning in 2003) and is the longest continuously operating SX/EW (solution extraction/electrowinning) plant in the world (since 1970). Phelps Dodge Corporation acquired the property in 1999 from Cyprus Amax Minerals Co. (Phelps Dodge Corporation, 2007).

The Mineral Park Mine, located in the Sacramento Valley Basin northwest of Kingman, operated a milling operation from 1964 to 1980 that produced a total of 646.4 million pounds of copper, 46.8 million pounds of molybdenum and 5 million ounces of silver as concentrate. Milling operations ceased in 1980 due to changes in ownership and low metals prices. Mercator Minerals Ltd. has recently acquired the property and plans to increase copper production from the current level of approximately 6 million pounds of copper per year through a phased expansion to include enlarging the existing SX/EW plant capacity and eventual construction of a milling operation to process copper-molybdenum resources found at lower depths (Mercator Minerals, 2005). Current water use is about 250 acre-feet a year.

The only other mining activities in the planning area are associated with small mines/quarries, principally sand and gravel operations in the Hualapai Valley, Lake Havasu, Lake Mohave and Peach Springs basins. Some of these operations are identified on the cultural demand maps for these basins. Water is used for aggregate washing, dust control, vehicle washing, and equipment cooling. Typically, there is relatively little water consumed at these sites.

There are four power plants in the planning area. The hydroelectric plants at Hoover Dam and Davis Dam in the Lake Mohave Basin are not considered direct consumers of water so their associated water demand is not included in Table 4.0-12. However, they are prominent industrial facilities in the planning area and are briefly described below.

The Hoover Dam and power plant were authorized by the Boulder Canyon Project Act of 1928 with electrical generation as one of its purposes. The power plant generators are used primarily to generate a low-cost peaking resource. The demand for Hoover power generation is seasonal, with the low-demand period in the winter months, and is a direct function of river flow and downstream water demands. The power plant generators operate in conjunction with the Davis and Parker power plants to provide maximum power generation with efficient use of water resources. The plant has a net generation capacity of more than 4,719,323 megawatt hours (MWh) (BOR, 2006c). Davis Dam was authorized under provisions of the Reclamation Project Act of 1939. Power generated from the power plant is marketed to wholesale customers in Arizona, Southern California, and Southern Nevada after priority use power obligations have been met. Davis generation is the direct result of downstream irrigation needs. Net power generation is about 968,615 MWh (BOR, 2005).

The South Point power plant is located on the Fort Mojave Indian Reservation in the Lake Mohave Basin. The 540-megawatt natural gas-fired plant with two gas-combustion turbines began operations in 2001. It is operated as a “merchant plant”, meaning that the energy generated at the plant is sold on the open market. The Fort Mojave Tribe has a 50-year lease with Calpine, an independent power company, for both the site and the water that the plant uses. The average annual use during 2001-2003 was estimated at about 3,600 acre-feet per year of Fort Mojave Indian Colorado River entitlement water (BIA, 1998).

The 600-megawatt Griffith power plant, also a merchant plant, is located about 15 miles southwest of Kingman. It began commercial operation in January 2002 and was sold in May, 2006 to LS Power Equity Partners. An estimated 1,600 acre-feet of groundwater is used at the plant each year.

Because of the relative remoteness of the area and its proximity to regional power grids, the Upper Colorado River Planning Area has become an attractive location for new power plants. LS Power is proposing to construct a 175-megawatt peaking plant adjacent to the Griffith plant that would come on line by 2008 or 2009. The source of water would be a portion of the groundwater already allocated to the Griffith plant through the Mohave County Water Authority. A 720-megawatt plant proposed in the Big Sandy Basin near Wikieup was turned down by the Arizona Corporation Commission (ACC) in November, 2001 primarily due to concerns about environmental impacts. It was the first plant to be denied a certificate by the ACC (ACC, 2001).

There are three "industrial" golf courses in the planning area, all located in the Lake Mohave basin. Industrial courses receive at least some water from facility wells and not from a municipal water provider. The Desert Lakes Golf Club, El Rio Country Club and Riverview Golf Club in the Lake Mohave Basin are considered industrial facilities. Industrial groundwater demand is about 356 acre-feet/year for the three golf courses. The Desert Lakes Golf Club and the Riverview Golf Club also use municipal effluent as shown in Table 4.0-10.

A dairy operated in the Sacramento Valley from 1947 to 2005. During that time, the dairy facility used about 76 acre-feet of groundwater a year.

4.0.8 Water Resource Issues in the Upper Colorado River Planning Area

Water resource issues have been identified in the Upper Colorado River Planning Area by community watershed groups, through the distribution of surveys, and from other sources. As discussed further below, primary issues are: limited water supplies, projected growth, limited groundwater data, aging water infrastructure and drought.

Planning and Conservation

Mohave County was the fastest growing county in Arizona between the 1990 and 2000 Census and proposed developments in the northwestern part of the planning area are causing concerns about the availability of water supplies to meet future needs. Mohave County has indicated it will oppose developments without a demonstration of adequate water supply. General and comprehensive plans and the water supply plans mentioned in Section 4.0.5 help planning area jurisdictions and water systems better prepare for the challenges associated with rapid growth.

Lake Havasu City has had a water conservation plan credited with reducing per capita water use for a number of years. Components include an increasing block rate water rate structure, low water use landscape requirements for certain lot sizes, no-turf policy for commercial, industrial and multi-family property and effluent reuse (Lake Havasu City, 2006). The City of Bullhead City also has a water conservation program and has entered into subcontract agreements with the three water companies that serve water within the City to implement water conservation practices. Practices include turf restrictions, an incentive program to use reclaimed water and leak detection and repair. There also is an incentive program to retrofit existing homes and commercial buildings with low-flow plumbing fixtures (BOR, 2006b). The City also offers a Landscape Rebate Program to convert grass to low water use plants.

The Hualapai Tribe has adopted several ordinances to protect water resources including a Water Resource Ordinance to ensure water quality, a Wetlands Protection and Preservation Ordinance, and a Drought Contingency Plan that establishes drought declaration criteria and identifies response actions (Hualapai Tribe, 2007).

Watershed Groups and Studies

Two watershed groups have formed in the planning area to address a variety of water resource issues. One of the groups, the Northwest Arizona Water Council, is currently active. A complete description of group participants, activities and issues is found in Appendix B. Primary issues identified by the two groups are summarized as follows:

Growth:
- Large master-planned communities planned in Detrital Valley, Hualapai Valley and Sacramento Valley basins as a result of completion (2010) of the bypass bridge across the Colorado River
- Unregulated lot splits

Water Supplies and Demand:
- Limited groundwater data
- Limited groundwater supplies

Legal:
- Concerns regarding proposed development that may use Colorado River water

Water Quality:
- Concerns related to mining activities
- Concerns regarding hexavalent chromium

Funding:
- Limited funding resources for planning, projects, infrastructure, and studies

Drought:
- Impacts on private water companies and water haulers
- Vulnerability of surface and groundwater supplies

Other:
- Potential for subsidence due to rapid growth
- Infrastructure of some private water provider systems in poor shape

In response to concerns by local governments, waters providers and citizens groups about the impacts of groundwater development, the Department, in collaboration with the USGS and with funding assistance from Mohave County, began conducting hydrogeologic investigations in 2005 to improve the understanding of water resources in three basins within the planning area; the Detrital Valley, Hualapai Valley and Sacramento Valley basins. These investigations will assess existing data collection networks and examine the current state of knowledge of the groundwater system; improve understanding of geologic units and their relationship to groundwater storage and movement; improve knowledge of groundwater budget factors including recharge and storage; evaluate groundwater quality; establish a hydrologic monitoring network for on-going assessment of the aquifer; and inform the hydrologic community and area residents about hydrologic conditions

(USGS, 2006). As part of this effort, the Department has released a preliminary estimate of groundwater in storage for the Detrital Valley Basin (ADWR, 2006)

Issue Surveys

The Department conducted a rural water resources survey in 2003 to compile information for the public and help identify the needs of growing communities. This survey also was intended to gather information on drought impacts to incorporate into the Arizona Drought Preparedness Plan, adopted in 2004. Questionnaires were sent to almost 600 water providers, jurisdictions, counties and tribes. A report of the findings from the survey was completed in 2004 (ADWR, 2004).

There were 18 water provider and jurisdiction respondents in the Upper Colorado River Planning Area, and 11 of those numerically ranked issues. Respondents were asked to rank 18 issues, which can be grouped into three categories: infrastructure, water supply, and water quality. As shown in Table 4.0-13, issues related to water infrastructure and to water supply were ranked among the top five issues by a majority of respondents. Infrastructure concerns were related primarily to aging infrastructure in need of replacement and inadequate capital for infrastructure improvements. Water supply concerns ranked highly due primarily to concerns about adequate future supplies. Two respondents identified drought as one of their top concerns, which illustrates the often highly localized sensitivity to drought.

The Department conducted a second, more concise survey of water providers in 2004. This was done to supplement the information gathered in the 2003 survey in support of developing the Arizona Water Atlas, and to reach a wider audience by contacting each water provider directly. Through this effort, 30 water providers in the Upper Colorado River Planning Area, with a total of approximately 69,000 service connections, participated and provided information on water supply, demand, infrastructure and to rank a list of seven issues.

Table 4.0-13 Water resource issues ranked by 2003 survey respondents in the Upper Colorado River Planning Area (10 water providers and 1 jurisdiction)

Issue	Ranked as one of the top 5 issues (out of 18)	Percent of respondents
Need for additional supplies to meet future demand	6	55
Inadequate capital to for infrastructure improvements	4	36
Aging infrastructure in need of replacement	6	55

Source: ADWR 2004

With regard to the question of groundwater level trends in their service area, 16 respondents to this question reported as follows: 7 stable; 8 falling, and 1 variable. No provider reported rising water levels. Responses are shown by those basins with respondents in Table 4.0-14.

Table 4.0-14 Groundwater level trends reported by 2004 survey respondents by groundwater basin (16 respondents)

Basin	Stable	Falling	Variable
Bill Williams	1		
Detrital Valley		1	
Hualapai Valley		1	
Lake Havasu	2		
Lake Mohave	1	1	1
Meadview		1	
Peach Springs	1		
Sacramento Valley	2	4	

Source: ADWR 2005c

As part of the 2004 survey, water providers were asked to rank issues from 0 to 3 with 0 = no concern, 1 = minor concern, 2 = moderate concern and 3 = major concern. Of the 30 water providers that responded to this survey, 23 ranked issues. Although responses to the 2003 questionnaire are not directly comparable to the 2004 survey due to differences in the form and wording of the surveys, responses to issues are similar as shown in Table 4.0-15. Responses indicate that infrastructure concerns, drought, and concerns regarding inadequate supplies to meet future demands rank high among the respondents.

Table 4.0-15 Water resource issues ranked by 2004 survey respondents in the Upper Colorado River Planning Area (23 water providers)

Issue	Moderate concern	Major concern	Total	Percent of respondents reporting issue was a major or moderate concern
Inadequate storage capacity to meet peak demand	5	2	7	30
Inadequate well capacity to meet peak demand	2	4	6	26
Inadequate supplies to meet current demand	1	3	4	13
Inadequate supplies to meet future demand	3	5	8	35
Infrastructure in need of replacement	6	3	9	39
Inadequate capital to pay for infrastructure improvements	5	5	10	44
Drought related water supply problems	5	4	9	39

Source: ADWR 2005c

Table 4.0-16 shows how respondents to the 2004 survey within individual basins ranked the issues. Respondents from seven basins ranked issues, but only in six basins did respondents rank issues as of moderate or major concern. Concern about infrastructure and storage capacity was noted by respondents in all responding basins, and concerns about future supplies, well capacity and drought were noted in all but one basin.

Table 4.0-16 Number of 2004 survey respondents, by groundwater basin, that ranked the survey water resource issues a moderate or major concern (23 water providers total)

Issue	Detrital Valley (1)	Hualapai Valley (3)	Lake Havasu (5)	Lake Mohave (4)	Peach Springs (1)	Sacramento Valley (8)
Inadequate storage capacity to meet peak demand	1	1	2	1	1	3
Inadequate well capacity to meet peak demand	1	1	1	1		2
Inadequate supplies to meet current demand	1	1	1			2
Inadequate supplies to meet future demand	1	1	2	1		3
Infrastructure in need of replacement	1	1	3	1	1	4
Inadequate capital to pay for infrastructure improvements	1	1	6	2	1	4
Drought related water supply problems	1	1	1	2		5

Source: ADWR 2005c

4.0.9 Groundwater Basin Water Resource Characteristics

Sections 4.1 through 4.9 present data and maps on water resource characteristics of the nine groundwater basins in the Upper Colorado River Planning Area. A description of the data sources and methods used to derive this information is found in Section 1.3 of Volume 1 of the Atlas. This section briefly describes general information that applies to all of the basins and the purpose of that information. The information is organized according to the order in which the characteristics are discussed in Sections 4.1 through 4.9.

Geographic Features

Geographic features maps are included to present a general orientation to principal land features, roads, counties and cities, towns and places in the groundwater basin.

Land Ownership

The distribution and type of land ownership in a basin have implications for land and water use. Large amounts of private land typically translate into opportunities for land development and associated water demand, whereas federal lands are typically maintained for a purpose with little associated water use. State-owned land may be sold or traded, and is often leased for grazing and farming. The extent of state -owned lands is due to a number of legislative actions. The

State Enabling Act of 1910 and the Act that established the Territory of Arizona in 1863 set aside sections 2, 16, 32 and 36 in each township to be held in trust by the state for educational purposes. Other legislation authorized additional state trust lands for specified purposes, which are identified for each basin. (Arizona State Land Department, 2006).

Climate

Climate data including temperature, rainfall, evaporation rates and snowfall are critical components of water resource planning and management. Averages and variability, seasonality of precipitation, and long-term climate trends are all important factors in demand and supply planning.

Surface Water Conditions

Depending on physical and legal availability, surface water may be a potential supply in a basin. Stream gage, flood gage, reservoir, stockpond, and runoff contour data provide information on physical availability of this supply. Seasonal flow information is relevant to seasonal supply availability. Annual flow volumes provide an indication of potential volumetric availability.

The criteria for including stream gage stations in the basin tables are that there is at least one year of record, and annual streamflow statistics are included only if there are at least three years of record. There are different types of stations and those that only serve repeater functions were not included.

Flood gage information is presented to direct the reader to sources of additional precipitation and flow information that can be used in water resource planning. Large reservoir storage information provides data on the amount of water stored in the basin, its uses, and ownership. Because of the large number of small reservoirs, and less reliable data, individual small reservoir data is not provided. The number of stockponds is a general indicator of small scale surface water capture and livestock demand. Runoff contours reflect the average annual runoff in tributary streams. They provide a generalized indication of the amount of runoff that can be expected at a particular geographic location.

Perennial and Intermittent Streams and Major Springs

A map of perennial and intermittent streams is provided for each basin. For some basins, more than one source of information was used. Stream designations may not accurately reflect current conditions in some cases. Spring data were compiled from a number of sources in an effort to develop as comprehensive a list as possible. Spring data is important to many researchers and to the environmental community due to their importance in maintaining habitat, even from small discharges.

Groundwater Conditions

Several indicators of groundwater conditions are presented for each basin. Aquifer type can be a general indicator of aquifer storage potential, accessibility of the supply, aquifer productivity, water quality, and aquifer flux. Well yield information for large diameter wells is provided and is generally measured when the well is drilled and reported on completion reports. It was assumed that large diameter wells were drilled to produce a maximum amount of water and, therefore, their reported pump capacities are indicative of the aquifer's potential to yield water to a well. However,

many factors can affect well yields including well design, pump size and condition, and the age of the well. Reported well yields are only a general indicator of aquifer productivity. Specific information is available from well measurements conducted as part of basin investigations.

Natural recharge is typically the least well-known component of a water budget. Many of the estimates in the Atlas are derived from studies of larger geographic areas and all deserve further study. Similarly, estimates of storage are based on rough estimates and considerably more study is needed in most basins. Components of storage include aquifer depth and specific yield.

Water level data is from measured wells, usually collected during the period when the wells were not actively being pumped or only minimally pumped. Depth to water measurements are shown on mapped wells if there was a measurement taken during 2003-2004. The basin hydrographs show water-level trends for selected wells over the 30-year period from January 1975 to January 2005. Not all basins have a sufficient number of representative hydrographs.

The flow directions that are shown generally reflect long-term, regional aquifer flow in the basin and are not meant to depict temporary or local-scale conditions. However, flow directions in some basins indicate how localized pumping has altered regional flow patterns.

Water Quality

Water quality conditions impact the availability of water supplies. Water quality data was compiled from a variety of sources as described in Volume 1 Section 1.3. The data indicate areas where water quality exceedences have occurred previously, however additional areas of concern may currently exist where water quality samples have not been collected or sample results were not reviewed by the Department (e.g. samples collected in conjunction with the ADEQ Aquifer Protection Permit programs). It is important to note also that the exceedences presented may or may not reflect current aquifer or surface water conditions.

Cultural Water Demand

Cultural water demand is an important component of a water budget. However, without mandatory metering and reporting of water uses, accurate demand data is difficult to acquire. Municipal demand includes water company and domestic (self-supplied) demand estimates. Basin demand information comes from several sources in order to prepare as accurate an estimate as possible. Annual demand estimates have been averaged over a specific time period. This provides general trend information without focusing on potentially inaccurate annual demand estimates due to incomplete data.

Locations of major cultural water uses comes primarily from a 2004 USGS land cover study using LANDSAT satellite imagery collected between 1999 and 2001. This study may not represent recent changes. Supplementary data have been used in some basins, as noted. The cultural demand maps provide only general information about the location of water users.

Effluent generation data were compiled from several sources to provide an estimate of how much of this renewable resource might be available for use. However, effluent reuse is often difficult both logistically and economically since a potential user may be far from a wastewater treatment plant.

Water Adequacy Determinations

Information on water adequacy and inadequacy determinations for subdivisions, with the reason for the inadequacy determination provides information on the number and status of subdivision lots. Listing the reason for the inadequacy identifies which subdivisions have a demonstrated physical or legal lack of water or may have elected not to provide the necessary information to the Department. Briefly, developers of subdivisions outside of AMAs are required to obtain a determination of whether there is sufficient water of adequate quality available for 100 years. If the supply is determined to be inadequate, lots may still be sold, but the condition of the water supply must be disclosed in promotional materials and in sales documents.

In addition to these subdivision determinations for which a water adequacy report is issued, water providers may apply for adequacy designations for their entire service area. There are eight Designations of Adequate Water Supply in the planning area. If a subdivision is to be served water from one of these water providers, then a separate adequacy determination is not required. (See Section 4.0.5).

Developers of large, master-planned communities outside of AMAs typically apply for an Analysis of Adequate Water Supply (AAWS). This type of application is used generally to prove that water will be physically available for the master-planned community. AAWS are issued based on the development plan or plat. If an AAWS is issued for groundwater, it reserves a specific volume of water for 10 years (for purposes of other adequacy reviews) only for the specific property that is the subject of the AAWS. (See Appendix A, Volume 1 for more information about the Adequacy Program).

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