BEYOND THE COLORADO RIVER: IS AN INTERNATIONAL WATER AUGMENTATION CONSORTIUM IN ARIZONA'S FUTURE?

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I. INTRODUCTION

In his book *Beyond the Hundredth Meridian*, Wallace Stegner wrote, "Water is the true wealth in a dry land; without it, land is worthless or nearly so."[1] In Arizona, water is the state's lifeblood, allowing people, crops, wildlife, and industry to thrive, even in a desert. In order to obtain the highest return on its value, however, the use of water must be carefully and thoughtfully planned, developed, and managed. Current residents of Arizona are the beneficiaries of the state's past leaders who had the vision to plan for, invest in, develop, and manage, the water resources we depend on today.

Arizona's burgeoning population is reaping the benefits of work by visionaries like George Maxwell, Governor Sidney Osborne, and Senator Carl Hayden, whose pioneering efforts in the first half of the twentieth century, and earlier, allowed this desert state to flourish.[2] George Maxwell's efforts led to the

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1. WALLACE STEGNER, BEYOND THE HUNDREDTH MERIDIAN 226 (Houghton Mifflin 1954).

2. *See generally* JACK AUGUST, VISION IN THE DESERT: CARL HAYDEN AND HYDROPOLITICS IN THE AMERICAN SOUTHWEST (1999); DONALD J. PISANI, TO RECLAIM A DIVIDED WEST: WATER, LAW, AND PUBLIC POLICY 1848–1902 (1992); Charles A. Esser, *Second Session Opened*, ARIZ. REPUBLIC, June 19, 1947; Charles A. Esser, *Two Water Bills Filed with Solons: Enforcement Control Plans Offered For Consideration*, ARIZ. REPUBLIC, Jan. 23, 1948; *Groundwater Code Before Lawmakers*, ARIZ. TIMES, Jan. 22, 1948; *Osborn's Water Bill*, ARIZ. TIMES, Jan. 22, 1948; *Revised Groundwater Code Given to Solons for Study*, ARIZ. REPUBLIC, Mar. 5, 1948; *Sweeping Powers Asked in Ground Water Bill*,

formation of the 1902 Reclamation Act, which provided the means to develop the source of funds to finance the construction of Theodore Roosevelt Dam and to develop the Salt River Project. Governor Osborne had the foresight in the 1940s to recognize and begin the debate over the importance of protecting Arizona's groundwater supply from excessive pumping. Senator Hayden spent much of his long career of public service securing funding for the Central Arizona Project ("CAP")—the water supply that sustains much of the current population growth in central Arizona.

Because of the foresight of these leaders, and others, Arizona's residents have sufficient water supplies to sustain their current and projected water demands for the near future. However, Arizona's population is growing at a tremendous rate and its sustainable water supplies are limited. Further, there is a growing interest in protecting and enhancing Arizona's unique natural environment that, in many places, is dependent on the availability of water. In order to continue to provide sufficient water supplies for its citizens without negatively impacting Arizona's ecosystems, leaders must begin allocating funds to plan and develop additional water resources for the future.

In this paper, the Authors review the historic, current, and future trends in Arizona's population growth and water use, and assess whether the state's current water supplies are adequate to serve its citizens in the future. The analysis indicates that in the majority of the state's most populous areas—Cochise, Coconino, Gila, Maricopa, Mohave, Pima, Pinal, and Yavapai counties—the current available renewable water supplies are not sufficient to sustain the projected population and preserve the distinctive natural environment in the future.

Because additional municipal water supplies will be needed in the future, the Authors evaluate several options for augmenting the state's water supplies and recommend an approach to initiate planning the development of such supplemental supplies. A review of these options suggests that Arizona will need to go beyond the Colorado River for its next water supply. The most viable option for Arizona appears to be development of an international water augmentation consortium with Mexico. The consortium would seek to develop a new freshwater supply for both Arizona and Mexico created through the desalination of ocean water from the Gulf of California.

Developing a water augmentation consortium with Mexico will be a monumental undertaking, not unlike the twentieth-century development of water supplies currently used by the United States and Mexico from the Colorado River. Creating the consortium and the necessary freshwater supplies will require the same farsighted leadership Arizona has benefited from in the development of its past water supplies. Arizona will need a visionary to champion this cause and to inspire the state's political, business, scientific, and engineering leaders. This multifaceted collaboration is essential to develop the necessary relationships with Mexico, the research and development of technologies to support implementation of a large-scale desalination project, and a plan to manage the financing,

PHOENIX GAZETTE, Jan. 22, 1948; Bill Turnbow, *Legislators, Gov. Osborn Agree on Call: For Second Time State Water Code Will Be Subject*, PHOENIX GAZETTE, Mar. 5, 1948.

construction, and operation of the infrastructure needed to create and deliver the freshwater.

II. TRENDS IN ARIZONA'S POPULATION

For the last half of the twentieth century, Arizona was one of the fastest growing states in the country. Since 1950, Arizona's population has grown by nearly 600%, more than six times the United States growth rate for the same period (Figure 1). In 1950, the population of Phoenix was slightly more than 100,000. In the most recent census, Phoenix was home to more than 1,300,000 people.[3] Nine Arizona cities and towns now have a population greater than 100,000 people.[4]

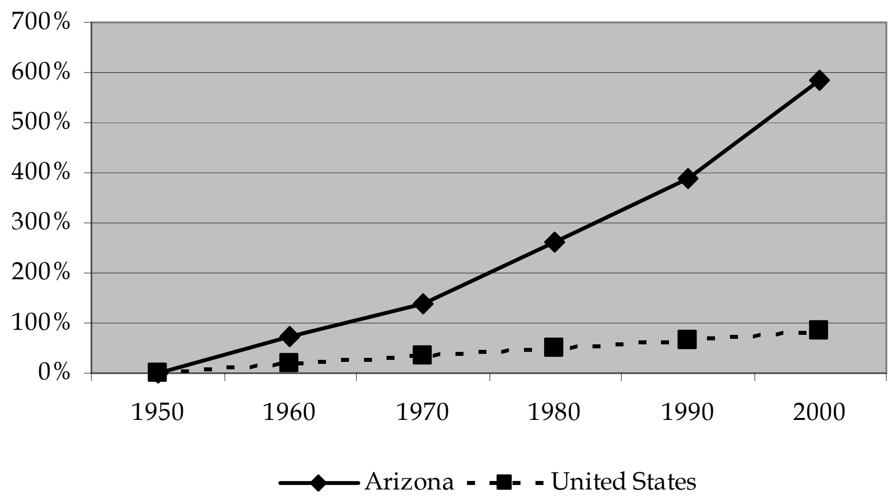

Figure 1. Population growth by percent in Arizona and the United States from 1950 to 2000.

Since 2000, Arizona's population boom has further escalated. In the last six years the state has gained nearly 1,000,000 new residents; its population has now surpassed 6,000,000. Some cities have experienced triple digit growth during this period: Maricopa (561%), Sahuarita (332%), El Mirage (289%), Queen Creek (268%), Surprise (154%), Buckeye (147%) and Goodyear (118%). Phoenix is now the sixth largest city in the United States; Tucson is ranked 32nd.[5] Geographically,

3. U.S. CENSUS BUREAU, GCT-PH1. POPULATION, HOUSING UNITS, AREA, AND DENSITY, *available at* http://factfinder.census.gov/servlet/GCTSubjectShowTablesServlet?_lang=en&_ts=193343158694 (select "GCT-PH1. Population, Housing Units, Area, and Density: 2000") (last visited Mar. 30, 2007).

4. *Id.*

5. U.S. CENSUS BUREAU, TABLE 1: ANNUAL ESTIMATES OF THE POPULATION FOR INCORPORATED PLACES OVER 100,000, RANKED BY JULY 1, 2005 POPULATION: APRIL 1, 2000 TO JULY 1, 2005 (2006), *available at* http://www.census.gov/popest/cities/SUB-EST2005.html (follow "Excel" hyperlink after title of report).

80.9% (4,985,544) of Arizona's current population resides in Maricopa, Pima, and Pinal counties ("Three County Area").[6] The next three most populous counties (Yavapai, Yuma, and Mohave) together comprise 9.5% (588,604) of Arizona's population.

Demographic experts forecast that Arizona's explosive growth will continue. The Arizona Department of Economic Security projects that Arizona will surpass the 10,000,000 mark in 2028 and reach over 13,300,000 by 2055.[7] By that time researchers predict that Phoenix and Tucson will have merged, and that the corridor from Prescott south to the Mexican border, including Sierra Vista, will grow into a megapolitan or "super-sized" metropolitan area, referred to as the Arizona Sun Corridor.[8] In 2055 Pinal County is expected to have quadrupled in population to more than 1,100,000 people, while the population in four other counties is projected to double (Maricopa, Mohave, Yavapai and Yuma). The Three County Area is expected to become home to 83.3% (11,112,290) of the state's population. Yavapai, Yuma and Mohave counties will continue to be the next most populous counties, but their proportion of the state's population is expected to drop slightly to 9%.

Still other researchers have projected that Arizona could grow to more than 18,000,000 people by 2100.[9] The population is expected to follow the same geographical patterns, although Pinal County is predicted to replace Pima County as the state's second most populous county (Table 1).

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6. U.S. CENSUS BUREAU, TABLE 1: ANNUAL ESTIMATES OF THE POPULATION FOR COUNTIES OF ARIZONA: APRIL 1, 2000 TO JULY 1, 2006 (2007), *available at* http://www.census.gov/popest/counties/CO-EST2006-01.html (follow "Excel" hyperlink under "Arizona").

7. ARIZ. DEP'T OF ECON. SEC., ARIZONA POPULATION PROJECTIONS 2006–2055 tbl.1 (2006), *available at* http://www.workforce.az.gov/?PAGEID=67&SUBID=138 (follow "excel" hyperlink after "Arizona State and County Projections 2006–2055: State of Arizona"). These projections may actually underestimate the number of persons that reside and use water in Arizona as they do not take into account (1) seasonal residents whose principal place of residence is in another state, and (2) undocumented residents who live in Arizona but are not permanent residents.

8. Catherine Reagor, *When Phoenix, Tucson Merge*, ARIZ. REPUBLIC, Apr. 9, 2006, at 1A.

9. Jim Holway, Peter Newell, and Terri Sue Rossi, Water and Growth: Future Water Supplies for Central Arizona 4 tbl.1 (June 13, 2006) (unpublished manuscript, on file with Global Institute of Sustainability, Arizona State University), *available at* http://sustainability.asu.edu/gios/waterworkshop.htm (follow "pdf" hyperlink after article title).

County	2020[10]	2040[11]	2060[12]	2080[13]	2100[14]
Apache	86,533	99,190	109,163	119,023	128,883
Cochise	169,717	201,179	225,372	249,936	274,500
Coconino	159,345	186,871	208,076	228,492	248,908
Gila	64,396	74,195	82,750	91,488	100,226
Graham	41,119	47,623	51,544	55,072	58,600
Greenlee	8,189	8,611	9,614	10,682	11,750
La Paz	25,487	29,715	32,382	35,180	37,978
Maricopa	5,276,074	7,009,664	8,209,097	9,347,117	10,485,137
Mohave	281,668	367,952	434,082	500,416	566,750
Navajo	147,045	180,054	204,644	229,022	253,400
Pima	1,271,912	1,585,983	1,831,622	2,075,670	2,319,718
Pinal	609,720	1,081,737	1,529,581	1,979,551	2,429,521
Santa Cruz	61,658	78,526	90,776	102,882	114,988
Yavapai	305,343	390,954	446,814	502,466	558,118
Yuma	271,361	351,299	403,258	454,280	505,302
Total	**8,779,567**	**11,693,553**	**13,868,772**	**15,981,274**	**18,093,776**

Table 1. Projected population by county in Arizona.

III. TRENDS IN ARIZONA'S WATER SUPPLY AND USE

Although Arizona has experienced explosive population growth, sound water management policies have enabled the state to provide adequate water supplies for new residents, while at the same time reducing the state's dependence on groundwater. Figure 2 shows the percentage of total water use from groundwater withdrawals and surface water diversions in Arizona from 1950 to 2000.

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10. ARIZ. DEP'T OF ECON. SEC., ARIZONA POPULATION PROJECTIONS 2006–2055 summary tbl. (2006), *available at* http://www.workforce.az.gov/?PAGEID=67&SUBID=138 (follow "excel" hyperlink after "Summary Population Projections 2006–2055: Projections for State and Counties").

11 *Id.*

12. Holway et al., *supra* note 9, at 4 tbl.1.

13. *Id.*

14. *Id.*

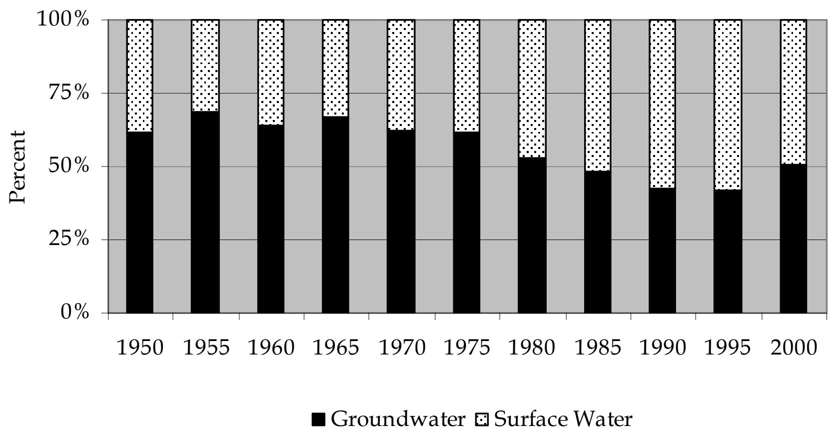

Figure 2. Percentage of total water use from groundwater withdrawals and surface water diversions in Arizona from 1950 to 2000.[15]

From the 1950s until the mid-1980s Arizona relied on groundwater for the majority of its water. During this period the rate of groundwater pumped from underground aquifers far exceeded their recharge, and water levels in wells throughout central Arizona decreased sharply. In addition to the significant loss of the groundwater supply, negative effects such as land subsidence and earth fissuring began to occur as a result of the over pumping. The state's past overuse of its groundwater system still impacts Arizona today.[16]

Recognizing that the continued overuse of groundwater supplies was not sustainable, Arizona's political leaders and water users agreed in 1980 to limit the use of groundwater in the state's most affected groundwater basins. The passage of the 1980 Groundwater Code ("Code")[17] also improved Arizona's prospects for receiving federal funding to complete the CAP. Largely as a result of the Code's limitations on groundwater use, the water use trend reversed in 1985. This new trend continues today, due in large part to the success of both the Code and CAP.[18] By the end of 2005, CAP had delivered nearly 20,000,000 acre-feet of Colorado River water into central and southern Arizona.

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15. A.D. KONIECZKI & J.A. HEILMAN, U.S. DEP'T OF THE INTERIOR, WATER-USE TRENDS IN THE DESERT SOUTHWEST—1950–2000, SCIENTIFIC INVESTIGATIONS REPORT 2004-5148, at 12 tbl.A (2004).

16. Lisa Nicita, *Governor Approves Bill to Identify, Map Fissures*, ARIZ. REPUBLIC, June 22, 2006, Chandler Republic, at 9; Lisa Nicita, *ADOT to Remedy Large Fissure on Route for Freeway*, ARIZ. REPUBLIC, July 17, 2006, Valley & State, at 1.

17. Groundwater Management Act, 1980 Ariz. Sess. Laws 4th Spec. Sess., ch. 1, § 86 (codified at ARIZ. REV. STAT. ANN. §§ 45-401 to -704 (2006)).

18. Since 1998, Arizona has been experiencing a nearly statewide drought that has temporarily caused the withdrawals of groundwater to exceed the diversions of surface water. This is reflected in the 2000 data. *See supra* Figure 2.

In addition to the changes in the source of water used in the state, there has also been a shift in how water is used. Figure 3 illustrates the growth in municipal and industrial uses as a result of the significant population growth in the state, and the decline in agricultural uses of water from 1950 to 2000. In 1950, agriculture used 97% of the state's water. In 2000, agricultural use comprised 80%, while the municipal and industrial sectors used 16% and 3%, respectively.[19]

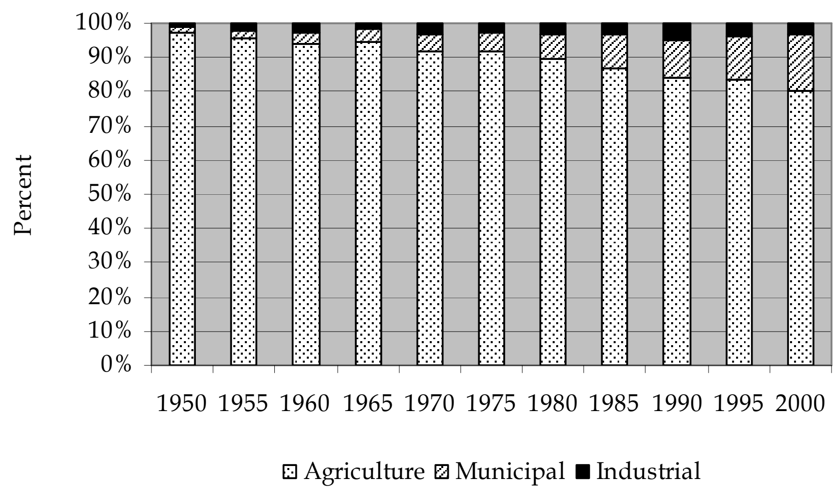

Figure 3. Percentage of water use by sector in Arizona from 1950 to 2000.

The most recent estimate by the Arizona Department of Water Resources puts the state's water use at 7,826,600 acre-feet per year (Table 2).[20]

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19. KONIECZKI & HEILMAN, *supra* note 15, at 9 tbl.2.

20. ARIZ. DEP'T OF WATER RES., 1 ARIZONA WATER ATLAS: INTRODUCTION, at 19 tbl.1-2 (2006) (draft).

Water Use Sector	Source of Supply and Amount of Water Used (acre-feet)				
	Groundwater[21]	**In-State Surface Water**	**Colorado River Water**	**Reclaimed Water**	**Total**
Agriculture	2,594,500	898,000	2,275,000	74,600	**5,822,100**
Municipal	662,600	418,200	421,900	94,000	**1,596,700**
Industrial	317,500	66,700	1,800	21,200	**407,200**
Total	**3,574,600**	**1,382,900**	**2,698,700**[22]	**189,800**	**7,826,000**

Table 2. Estimated water use by sector and water source in Arizona in 2003.

As noted earlier, the overall use of surface water continues to exceed the overall use of groundwater. Water use in the municipal sector now comprises 20% of the state's water use, while agricultural use represents 74%.

IV. ARIZONA'S CURRENT WATER SUPPLIES

Currently, Arizona's water supply is derived from four sources: (1) surface water from in-state rivers—the Gila River system and its tributaries (Salt, Verde, Santa Cruz, San Pedro, Agua Fria and Hassayampa), the Little Colorado River system, and the Bill Williams River system; (2) surface water from the Colorado River; (3) groundwater; and (4) effluent or reclaimed water.

The long-term average annual supply of surface water from Arizona's in-state rivers is estimated to be about 1,700,000 acre-feet. The vast majority of this water is either diverted and used directly from Arizona's rivers each year or is stored in reservoirs, e.g., Roosevelt Lake, San Carlos Lake, Bartlett Lake, etc., for use in subsequent years. Currently, on average, about 65% of the water that is diverted or stored each year is used for agricultural purposes and 30% is used for municipal purposes. The remaining 5% is used for industrial purposes. Additionally, about 150,000 acre-feet per year are used on Indian reservations. The vast majority of this water is used for agricultural purposes.

Arizona is entitled to use 2,800,000 acre-feet of water from the Colorado River each year.[23] This water has been allocated among various water users under several different priorities. Water users along the mainstem of the Colorado River are projected to consume about 1,300,000 acre-feet. The majority of this

21. Includes pumping for drainage purposes. The majority of the drainage pumping in Arizona (approximately 250,000 acre-feet per year) is associated with agricultural water uses along the Colorado River and is reflected in the figures for agricultural groundwater use.

22. Does not include approximately 400,000 acre-feet of CAP water recharged in central Arizona.

23. 43 U.S.C. § 617c(a) (2000).

entitlement carries the highest priority; however, approximately 150,000 acre-feet shares the most junior priority with CAP (see below). Agriculture uses about 90% of the mainstem Colorado River supply. About 800,000 acre-feet of the agricultural water is diverted for use on Indian reservations.

The remaining 1,500,000 acre-feet of Arizona's Colorado River water supplies are allocated to the CAP.[24] The CAP entitlement is further allocated among non-Indian and Indian water users. The vast majority of the non-Indian CAP supplies are allocated to municipal and industrial uses and, pending approval of the Gila River Indian Community Water Rights Settlement Agreement, total 747,276 acre-feet. The Indian CAP allocation is 667,724 acre-feet. Of the total Indian allocation, 154,000 acre-feet has been leased to municipal water providers on a long-term basis.[25] The entire CAP entitlement (plus the 150,000 acre-foot mainstem allocations—see above) is currently regarded as the most junior Colorado River supply among the seven states who share its supply, and is therefore less likely to be fully available during periods of extended drought in the Colorado River Basin.[26]

Arizona's groundwater supply is highly variable and, in certain areas (Active Management Areas or "AMAs"), highly regulated. In the central and southern areas of the state (Phoenix, Pinal, and Tucson AMAs) the groundwater supply is quite extensive; however, its use is limited by the requirements of the Code.[27] Northeast Arizona (most of Apache and Navajo counties and parts of Coconino County) also contains significant groundwater reserves. In some parts of the state, groundwater is interconnected with surface water (areas adjacent to perennial and intermittent streams in the Gila, San Pedro, Salt, Verde, Santa Cruz, Bill Williams, Hassayampa, and lower Colorado River watersheds). Consequently, the use of groundwater in these areas may be limited in the future, depending on the actual availability of groundwater and the quantity of stream flow available to surface water users, because most uses of water withdrawn from wells near streams are junior in priority to uses initiated by direct diversion from streams. In still other areas of the state, groundwater is contained in hard rock aquifers and is often difficult to extract in large volumes on a sustained basis. These areas include Payson, Pine, Strawberry, Williams, and Flagstaff.

Reclaimed water is produced from the wastewater (effluent) derived from the use of water by people. Currently, it estimated that about 479,000 acre-feet of effluent is produced each year in Arizona. Effluent is treated (reclaimed water) and

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24. The actual quantity of CAP water that has been allocated for delivery is 1,415,000 acre-feet. The remaining 85,000 acre-feet is lost through evaporation and seepage during delivery in the CAP aqueduct.

25. *See* Holway et al., *supra* note 9, at 17, 22 tbl.5.

26. 43 U.S.C. § 1521(b).

27. Under the assured water supply rules, however, there are several types of authorizations to pump groundwater that are considered renewable for purposes of groundwater regulation: (1) Pre-rules groundwater (about 75,000 acre-feet/year); (2) Incidental recharge (4% of municipal demand); (3) Allowable groundwater use (about 80,000 acre-feet/year); and, (4) AMA water farms/imported groundwater (estimated to be about 123,000 acre-feet/year). See Holway et al., *supra* note 9, for a more detailed explanation of these renewable groundwater supplies.

is reused for a variety of purposes, most of which are agricultural or industrial. As the state continues to grow in population, the amount of reclaimed water produced for future uses will increase. It is expected that over time the percentage of effluent reclaimed for future use will increase as the infrastructure to deliver reclaimed water expands into new urban development areas.

V. ARIZONA'S FUTURE: MUNICIPAL WATER DEMANDS AND AVAILABLE RENEWABLE WATER SUPPLIES[28]

Given the state's projected population growth, one of the most significant issues for Arizona to address will be whether the state has sufficient water supplies to sustain its projected municipal water demands. Determining whether Arizona's water supplies are sufficient for the future requires an assessment of the future municipal water demands and the amount of water available to supply these demands.[29]

For purposes of this analysis, we use the population projections in Table 1 (2020 to 2100) and the current representative gallons-per-capita-per-day (GPCD) rates of water providers in each county to estimate future municipal water demands. As previously noted, these population projections likely underestimate the total population using water in Arizona because seasonal and undocumented residents are not included in the state's population projections.[30] Table 2 shows the projected water demands in the municipal sector for each county in 2020, 2040, 2060, 2080, and 2100. Municipal water demand in Arizona is expected to increase by nearly 300%, from 1,596,700 acre-feet today to 4,195,512 acre-feet in 2100.

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28. For purposes of this analysis, municipal water demand includes self-supplied domestic uses.

29. For purposes of this analysis, we assume that municipal water demands will be met mostly from renewable water supplies—surface water, renewable groundwater, and reclaimed water, and not mined groundwater. Renewable groundwater is groundwater that is replenished from natural and artificial recharge over a long-term period and is available for use without depleting the overall groundwater supply or discharge to springs and streams. Mined groundwater is groundwater that is not renewable over a long-term period and results in long-term depletions to the overall groundwater supply and discharge to springs and streams.

30. *See supra* note 7.

County	Est'd GPCD	Projected Municipal Demand				
		2020	2040	2060	2080	2100
Apache	150	14,539	16,666	18,342	19,998	21,655
Cochise	175	33,269	39,436	44,179	48,994	53,809
Coconino	150	26,773	31,398	34,961	38,392	41,822
Gila	150	10,820	12,466	13,904	15,372	16,840
Graham	175	8,060	9,335	10,104	10,795	11,487
Greenlee	150	1,376	1,447	1,615	1,795	1,974
La Paz	220	6,281	7,323	7,980	8,669	9,359
Maricopa	220	1,300,192	1,727,403	2,022,981	2,303,425	2,583,870
Mohave	220	69,412	90,675	106,972	123,318	139,665
Navajo	150	24,707	30,253	34,385	38,481	42,577
Pima	175	249,327	310,893	359,044	406,884	454,723
Pinal	200	136,595	242,340	342,670	443,476	544,283
Santa Cruz	175	12,087	15,393	17,794	20,167	22,541
Yavapai	175	59,855	76,637	87,587	98,496	109,405
Yuma	250	75,991	98,376	112,927	127,215	141,503
Total		**2,029,283**	**2,710,042**	**3,215,444**	**3,705,478**	**4,195,512**

Table 3. Projected municipal water demands by County from 2020 to 2100.

There are several approaches that could be used to derive an estimate of the quantity of renewable water supplies available to supply future municipal water demands. One approach would be to assume that all of the renewable water supplies in Arizona could be used to serve municipal uses. Under this statewide demand versus supply approach, the task would then be as simple as adding up all the supplies described previously and then comparing them to the projected municipal water demand. Table 4 presents these data. With this approach, the projections suggest that Arizona could easily supply its municipal water demands well into the future.

Water Source	Quantity (acre-feet)				
	2020	2040	2060	2080	2100
In-State Surface Water	1,700,000	1,700,000	1,700,000	1,700,000	1,700,000
Colorado River Water	2,715,000	2,715,000	2,715,000	2,715,000	2,715,000
Groundwater[31]	281,171	363,402	406,618	426,219	445,820
Reclaimed Water[32]	152,196	203,253	482,317	555,822	629,327
Total Renewable Water Supplies	**4,848,367**	**4,981,655**	**5,303,935**	**5,397,041**	**5,490,147**
Projected Municipal Water Demands	**2,029,283**	**2,710,042**	**3,215,444**	**3,705,478**	**4,195,512**
Surplus (Deficit)	**2,819,084**	**2,271,613**	**2,088,491**	**1,691,563**	**1,294,635**

Table 4. Estimated total quantity of renewable water supplies in Arizona by water source and projected municipal water demands. These estimates assume that all renewable supplies are available for use in the municipal sector.

However, for several reasons, this type of approach is not realistic. First, a "statewide" analysis of water supply and demand does not consider the geographic variability of the legal entitlements to water supplies available to different parts of the state. While water users have, on occasion, managed to work out arrangements to exchange water supplies in one area of the state for water supplies in another area, the number and size of these exchanges is generally limited by (1) the available supply at the point where the exchange takes place, (2) water rights interests of third parties, and (3) environmental concerns. Consequently, a statewide approach masks the actual legal and physical availability of water to supply future municipal uses in different areas of the state.

Second, this approach fails to consider that the amount of precipitation and runoff from the state's watersheds and from the Colorado River Basin does not provide an average supply of renewable water every year. While the state is fortunate to have a number of large reservoirs to capture water in above average years of runoff, research shows that drought periods can be extensive enough in both length and magnitude to easily deplete the reservoir supplies.[33] Groundwater

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31. Includes incidental recharge from municipal use (4% of municipal water demand), and AMA renewable groundwater. *See supra* note 27.

32. Assumes 30% of projected municipal demand will be available as effluent. In 2020 and 2040, we assume 25% of the effluent will be reclaimed and reused for drinking water purposes and after 2040, we assume 50% will be reclaimed and reused for drinking water purposes.

33. *See* KATHERINE K. HIRSCHBOECK & DAVID M. MEKO, A TREE-RING BASED ASSESSMENT OF SYNCHRONOUS EXTREME STREAMFLOW EPISODES IN THE UPPER COLORADO & SALT–VERDE–TONTO RIVER BASINS 17 (2005), *available at*

is a good short-term backup supply, but it can easily be shortsightedly overused, as Arizona history has demonstrated. Accordingly, projecting the quantity of renewable water to serve future municipal uses must take into account the variability in the availability of surface water supplies.

A third shortcoming of this approach is that it does not consider that much of Arizona's renewable water supplies are used for agricultural purposes in areas of the state that are not projected to grow significantly in population over the next 100 years. The expectation of being able to transfer agricultural water from rural communities to other areas of the state that are predicted to grow significantly in population must take into account the long-established legal, economic, and cultural interests of those who depend on that water, and the political, institutional, geographical, and physical constraints associated with such proposed transfers.

For example, in the upper Gila River watershed (Graham and Greenlee counties) there is a significant supply of surface water from the Gila River (approximately 125,000 acre-feet) that is currently used by farmers in the Safford and Duncan Valleys. This quantity of water is much greater than the combined long-term projected municipal water demand in Graham and Greenlee counties (2100: approximately 13,400 acre-feet). If the entire municipal demand in these two counties in 2100 came from the Gila River, the farmers would still have entitlements to approximately 110,000 acre-feet. Legally, culturally, economically, and institutionally this water belongs to the upper Gila River farmers, the surrounding communities, and its businesses. Because of these factors, it is likely that any attempt to transfer this water to another watershed to serve municipal uses would be strenuously resisted by many upper Gila River watershed interests. Additionally, the Gila River Indian Community and the San Carlos Irrigation District would likewise resist the proposed transfer because the water users of both of these entities share an interest in the Gila River water for the San Carlos Irrigation Project.

Consequently, while "on paper" there appears to be approximately 110,000 acre-feet of surface water from the upper Gila River watershed available to serve municipal water uses somewhere in the state in the future, because of the factors discussed above, this water will likely remain in the watershed for use by farmers and others.

A more reasoned approach to assess whether Arizona has sufficient renewable water supplies to serve its projected municipal water demand would be to identify the renewable water supplies that could reasonably be considered available for future use in the municipal sector. These supplies would include (1) supplies currently used for municipal purposes (surface water, reclaimed water and renewable groundwater), (2) supplies that are under contract but are not currently being fully used for municipal purposes, e.g. CAP water, and (3) supplies that are currently utilized for other purposes but could reasonably be considered for conversion or transfer to municipal uses taking into account the legal, economic,

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http://fp.arizona.edu/kkh/SRP/
Final.Report/Final.Final.Report.pdf.

cultural, institutional, political, geographical, and physical constraints associated with such changes in use.

To determine this amount of water, however, it is necessary to make certain assumptions about (1) the allocation and management of water in Arizona and how it affects the availability of various water sources that are, or could be, used to serve municipal uses, and (2) future uses of water for municipal, agricultural, industrial and fish and wildlife uses in Arizona. These assumptions are described below.

A. Water Allocation and Management Assumptions

1. The water user requirements and water management goals applicable to the groundwater basins regulated by the Groundwater Code will remain in place. Accordingly, municipal water providers in the AMAs will be required to continue to secure renewable water supplies for new urban developments.

2. The Arizona Water Settlements Act of 2004 will become effective. Accordingly, the Final Decision of CAP Water Reallocation will become effective.[34]

3. Arizona's in-state surface water supplies will be declared fully appropriated and will be adjudicated to those with existing decreed rights and those who lawfully initiated rights to use water under state and federal law. Surface water rights associated with non-Indian agricultural uses will eventually be converted to (1) municipal use as agricultural lands urbanize or (2) fish and wildlife uses. However, some transfers to new locations to serve municipal uses in the watershed of origin will take place in rural areas. Indian entitlements to in-state surface water will be used on their reservations in accordance with settlement agreements.

4. The Arizona Supreme Court's order regarding subflow will be implemented in the General Stream Adjudications.[35]

5. The water supplies set forth in the settlement agreements for the Ak-Chin, Ft. McDowell, Salt River, San Carlos, Yavapai-Prescott, Gila River, Tohono O'odham, Zuni, and Quechan Tribes, and the decreed entitlements of the Colorado River, Fort Mojave, and Cocopah Tribes will be sufficient to supply the water uses contemplated on their respective reservations. Accordingly, these Indian Tribes will not need additional water supplies prior to 2100.

6. Indian Tribes legally authorized to lease allocations of Colorado River water will continue to lease more, but not all, of their allocations.

B. Water Use Assumptions

1. Given the expected population increases in Arizona, the use of water in the municipal sector will continue to increase. Municipal water providers outside

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34. Central Arizona Project (CAP), Arizona; Water Allocations, 71 Fed. Reg. 50,449-02, 50,449–52 (Aug. 25, 2006).

35. *In re* Gen. Adjudication of All Rights to Use Water in the Gila River Sys. & Source (*Gila IV*), 9 P.3d 1069 (Ariz. 2000).

AMAs currently overlying and dependent on groundwater supplies that are (1) interconnected with surface water or (2) from hard rock aquifers will move toward acquiring legal entitlements to renewable water supplies. Municipal water providers outside AMAs in regions where sufficient groundwater reserves exist, including sufficient natural recharge to the groundwater system, will continue to use groundwater as their primary supply.

2. Overall, agricultural use will continue to decline, although there will be an increase in agricultural use on Indian Reservations as Indian communities begin to use water supplies obtained in their settlement agreements. In some parts of the state—Yuma, La Paz, Graham, and Cochise counties—new non-Indian agricultural land may be developed. However, these new uses will be relatively small and will be supplied by groundwater and, accordingly, will not compete with the municipal sector for renewable water supplies.

3. Self-supplied industrial uses will increase at a modest rate; however, all major industrial users will be supplied by groundwater or surface water in areas with sufficient supplies to satisfy both municipal and industrial demands, or reclaimed water provided by municipal water providers. As a result, industrial users will generally not compete with the municipal sector for renewable water supplies.

4. There will be an increasing interest and an environmental requirement to preserve and enhance stream flows in Arizona's streams for protection of habitat for fish and wildlife. This will further limit access to interconnected groundwater.

Given these assumptions, Table 6 shows a more reasoned projection of the amount of renewable water supplies by water source on a statewide basis, along with the projected municipal water demands. This estimate is derived from an analysis of the availability of the following water sources:

1. In-state surface water supplies available for use in the municipal sector are estimated to be 725,000 acre-feet in 2020 and increase to 1,100,000 acre-feet as surface water rights are converted or transferred to serve municipal uses in response to urbanization in Apache, Maricopa, Pinal, Navajo, Graham, and Yavapai counties. The remaining in-state surface water supplies would not be converted or transferred to the municipal sector. These supplies include: (1) non-Indian water supplies in the Gila, Salt, San Pedro, Bill Williams, Hassayampa and Little Colorado River watersheds that will remain in the agricultural, industrial, and fish and wildlife sectors, and (2) Indian water supplies in the Gila, Salt, and Verde watersheds that will continue to be used on Indian Reservations for agricultural and industrial purposes.

2. Colorado River supplies are estimated to be 1,059,664 acre-feet in 2020 and increase to 1,149,664 acre-feet in 2100. They include the following components:

Colorado River Allocation Components	Quantity (acre-feet)				
	2020	2040	2060	2080	2100
Non-Indian CAP	720,664	720,664	720,664	720,664	720,664
Current CAP Leases	154,000	154,000	154,000	154,000	154,000
Future CAP Leases	25,000	25,000	25,000	25,000	25,000
Mainstem M&I Entitlements	140,000	140,000	140,000	140,000	140,000
Non-Indian Agriculture Conversion	20,000	50,000	80,000	100,000	120,000
Total	**1,059,664**	**1,089,664**	**1,109,664**	**1,129,664**	**1,149,664**

Table 5. Colorado River supplies projected to be available for municipal purposes from 2020 to 2100.

3. Groundwater supplies are estimated to be 323,781 acre-feet in 2020 and increase to 511,584 acre-feet in 2100. These amounts are slightly higher than the amounts shown in Table 3 and now include additional pumping to serve relatively small amounts of municipal demands in several counties outside of AMAs (Apache, Graham, Greenlee, La Paz, and Navajo counties).

4. The reclaimed water supplies are the same as in Table 3.

Water Source	Quantity (acre-feet)				
	2020	2040	2060	2080	2100
In-State Surface Water	725,000	825,000	950,000	1,050,000	1,100,000
Colorado River Water	1,059,664	1,089,664	1,109,664	1,129,664	1,149,664
Groundwater[36]	323,781	413,299	461,851	486,718	511,584
Reclaimed Water[37]	152,196	203,253	482,317	555,822	629,327
Total Renewable Water Supplies	**2,260,641**	**2,531,216**	**3,003,832**	**3,222,204**	**3,390,575**
Projected Municipal Water Demands	**2,029,283**	**2,710,042**	**3,215,444**	**3,705,478**	**4,195,512**
Surplus (Deficit)	**231,358**	**(178,826)**	**(211,612)**	**(483,274)**	**(804,937)**

Table 6. Revised estimate of the amount of renewable water supplies by source in Arizona. These estimates consider projected uses and limits on the transfer of some water sources.

Unlike the previous statewide projections, these projections suggest that Arizona's municipal water demand will exceed the amount of renewable water supplies available for municipal uses some time between 2020 and 2040. However, even this analysis underestimates the potential municipal water shortfall because it still compares projected statewide water availability with projected statewide municipal demands. In order to determine which areas of the state are projected to have sufficient water supplies to serve their future municipal demand and which do not, an analysis of supplies and demands by smaller regions of the state is necessary. For purposes of this analysis, we analyze water supplies and demands by county.

There are some counties in Arizona where a detailed analysis of the currently available water supplies is not necessary because either (1) the available surface water supplies are clearly sufficient to serve the projected demand or (2) the projected demand is significantly less than the combined amount of available renewable water and groundwater supplies. These counties include Apache, Graham, Greenlee, La Paz, Navajo, and Yuma. As discussed earlier, the surface water supplies available in Graham and Greenlee counties are clearly sufficient to serve the projected municipal demands well into the future. A similar situation

36. Includes incidental recharge from municipal use (4% of municipal water demand), and AMA renewable groundwater. *See supra* note 27.

37. Assumes 30% of projected municipal demand will be available as effluent. Prior to 2050, we assume 25% of the effluent will be reclaimed and re-used for drinking water purposes and after 2050, we assume 50% will be reclaimed and reused for drinking water purposes.

occurs in Yuma County, where the quantity of Colorado River water (existing municipal supplies and conversions and/or transfers of agricultural supplies) is more than sufficient to serve the projected municipal demands well into the future.

In Apache, La Paz, and Navajo counties the combined amount of surface water and groundwater is sufficient to serve the projected municipal demands in the future.[38] In La Paz County the annual municipal water demand in 2100 is projected to be approximately 9,400 acre-feet. The municipal providers in La Paz County have access to mainstem Colorado River water supplies as well as groundwater in sufficient quantities to serve this level of municipal demand, and greater, in the future. As for Apache and Navajo counties, the vast majority of the municipal providers in both counties withdraw groundwater from the C-aquifer, a very large aquifer that covers most of the northwest part of the state and has a very extensive area from which it is recharged. Additionally, in both counties, there are sufficient surface water supplies that could be converted or transferred for use in the municipal sector. We believe these supplies will eventually be used to supplement the groundwater sources and consequently sufficient water should be available in these counties to serve the projected municipal demands through 2100.

The remaining counties, Cochise, Coconino, Gila, Maricopa, Mohave, Pima, Pinal, Santa Cruz, and Yavapai, however, warrant a more detailed analysis of supplies and demands given their significant projected population growth and/or their projected limited water supplies. In fact, in three of these counties (Cochise, Mohave and Yavapai) there is significant concern today about whether sufficient water exists to serve the soaring population growth.

The Appendix shows the projected municipal water supplies and demands in these nine counties from 2020 to 2100 in table and graph form. A summary of these results are shown in Table 7.

38. There is some uncertainty regarding the supplies available for Indian municipal demands in these counties; however, we believe a portion of the Indian CAP supplies, the Cibola Valley Irrigation and Drainage District water acquired by the Hopi Tribe, and groundwater from the C-, N-, and alluvial aquifers will be sufficient to meet the Tribes' long-term municipal demands.

County	Quantity of Surplus or (Deficit) in acre-feet				
	2020	**2040**	**2060**	**2080**	**2100**
Cochise	(14,443)	(14,901)	(15,785)	(19,685)	(23,585)
Coconino	(18,694)	(22,788)	(23,319)	(26,097)	(28,876)
Gila	(5,576)	(7,033)	(7,262)	(8,451)	(9,641)
Maricopa	128,889	(166,693)	(213,556)	(390,716)	(617,875)
Mohave	8,570	4,753	3,353	(9,888)	(23,129)
Pima	81,179	72,450	43,361	14,675	(14,011)
Pinal	22,385	(61,280)	(94,145)	(160,861)	(252,579)
Santa Cruz	4,303	6,377	10,587	8,664	6,742
Yavapai	(9,972)	(19,824)	(17,945)	(24,282)	(33,118)
Total	**196,641**	**(208,939)**	**(314,711)**	**(616,641)**	**(996,072)**

Table 7. Projected surplus or deficit in renewable water supplies available to serve projected municipal water demands.

The projections show that a significant supply deficit exists in Cochise, Coconino, Gila, and Yavapai counties beginning in 2020 and continuing in to the future. These significant deficits exist for several reasons.

First, except for Yavapai County,[39] the amount of groundwater available in each of these counties has been limited to the estimated amount of incidental recharge occurring from the overall use of water in the municipal sector for that county. These amounts are less than what is currently being withdrawn in these counties for municipal use. However, in the major growth areas of each of these counties, there is presently a concern about the long-term sustainability of the region's groundwater supply. In parts of Coconino and Gila counties (Flagstaff, Williams, Payson, Pine, and Strawberry), the concern is primarily a matter of the physical sustainability of the area's groundwater supply, while in Cochise and Yavapai counties the concern relates to the legal availability of groundwater because much of the groundwater along the San Pedro River in Cochise County and the Verde River and its tributaries in Yavapai County is interconnected with surface water.

The relatively small amount of in-state surface water rights in these counties is another factor that affects the amount of the deficit. In each of these counties the projected amount of in-state surface water is less than 50% of the

39. In Yavapai County we have assumed additional groundwater pumping from the Big Chino Valley for importation into the Prescott AMA, and additional groundwater pumping in the Prescott AMA and Verde Valley equivalent to their current levels of groundwater pumping.

long-term municipal demand, and in most counties it is less than 30% (see Appendix). Additionally, only one of the municipal providers operating in these counties has an allocation of Colorado River water.[40] As a result, the long-term municipal demand in these counties is projected to greatly exceed the available renewable supply.

In Maricopa and Pinal counties the projections show that a sufficient water supply exists to serve the estimated municipal demand through 2020. However, in future years, the supply is anticipated to fall below the projected municipal demand. By 2100, the county municipal water supply deficits are substantial: Maricopa County (24% of total annual demand; approximately 620,000 acre-feet/year) and Pinal County (46% of total annual demand; approximately 252,000 acre-feet per year). The projections for Pima County show that sufficient supplies exist through 2080, but by 2100 the municipal demand exceeds the supply by about 3% (14,000 acre-feet/year). In Mohave County, the projections show that the renewable water supplies are nearly equivalent to the estimated municipal demand prior to 2060.[41] However, after 2060 the municipal demand is projected to be greater than the supply and by 2100 the supply shortfall is projected to be approximately 23,000 acre-feet per year or about 17% of the County's municipal water demand. Lastly, the projections for Santa Cruz County show that sufficient renewable water supplies exist in the county to serve the future municipal demands. Most of the available supply is surface water from the Santa Cruz River.

Again, the water demand projections used in this analysis are based on population projections and current estimated municipal water provider GPCD rates. In terms of water supplies, the projections consider (1) the changes in the allocations of CAP water embodied in the Arizona Water Settlements Act of 2004, (2) the limitations on groundwater use in AMAs and apply these principles to counties outside of AMAs where water supply and demand concerns are currently an issue because of population growth (Coconino, Cochise, Gila, Mohave, and Yavapai counties), (3) reasonable assumptions concerning the change in use and location of use of surface water rights currently used for agricultural purposes, and (4) that a full supply of in-state surface water and Colorado River water will be available for use every year.

On this last point, however, we know that Arizona's watersheds and those in the Colorado River Basin are subject to severe and extensive droughts. This is of particular concern for the CAP supply (including a portion of the mainstem Colorado River entitlement) because it is currently regarded as the most junior water entitlement on the Colorado River. While it is difficult to predict the severity of future droughts, Arizona has attempted to plan for shortages in the CAP supply by storing surplus CAP water in underground storage projects for future

40. Brooke Utilities, which operates two small water companies in Pine and Strawberry, has an allocation of 106 acre-feet of CAP water.

41. Of interest, the vast majority of the non-Indian renewable water supplies in Mohave County are mainstem Colorado River entitlements under contract to municipal providers along the Colorado River. Municipal providers who serve the planned high growth areas near Kingman currently do not have Colorado River entitlements.

withdrawal. However, even with the water storage program, given the recent research on drought cycles in the Colorado River Basin and the potential for increased water development in the upper Colorado River Basin, there remains some uncertainty about the quantity of CAP water that will be available to Arizona in the long-term. This concern exists for Arizona's in-state surface water sources as well. While Arizona has specifically planned for supplementing its CAP supplies during shortage years, there is no specific plan in place to augment Arizona's in-state surface water supplies during extended drought periods. Consequently, the actual water supply deficits could be even more severe than projected in this analysis.

In summary, given the assumptions described above, the projections show that in Arizona's most populous counties there may not be sufficient renewable water supplies to supply the projected municipal water demand beginning as early as 2020. In some counties, the supply deficits are substantial relative to the size of the projected county municipal demand (Coconino, Cochise, Gila, Mohave, and Yavapai counties), while in others the deficits are substantial in terms of overall magnitude (Maricopa and Pinal counties). The total volume of deficit is projected to be 1,000,000 acre-feet per year by 2100.

Again, these projections assume that a full supply of surface water is available every year. If the long-term availability of CAP water and the Arizona in-state surface water supplies are negatively impacted by drought and the effects of climate change, and the state's projected population continues as it has historically, the deficit between the water supply and the water demand could be even higher. While additional conservation and increased groundwater pumping might be acceptable solutions to offset these deficits in the short-term, they are not sustainable in the long-term. In order for Arizona to sustain its projected population in the future, the state will need to significantly augment its water supplies.

VI. Water Augmentation Options for Arizona

There are essentially two approaches that Arizona could pursue to augment the water supplies used in the eight counties projected to have insufficient renewable water supplies to serve the municipal water demand ("Eight County Area"). One approach would be to identify other supplies in Arizona that could be used for municipal purposes but have not been considered for this use in this analysis ("in-state options"). The other approach would be for Arizona to acquire a water supply from outside the state ("out-of-state options"). In this case the supply could be transferred and delivered directly to the state or it could be delivered to another water user in exchange for a commensurate amount of water delivered to Arizona.

A. In-State Options

There are two in-state options that could reasonably be considered to augment the water supplies used in the Eight County Area. One option would be to increase the percentage of effluent that could be reclaimed and used by municipal providers for drinking water purposes. Currently, less than 10% of the effluent produced in Arizona is reclaimed and used for drinking water purposes. The analysis in this Article assumes that up until 2040, 25% of the effluent produced would be reclaimed and used by municipal providers for drinking water, and after 2040, 50% of the effluent would be reclaimed and used for drinking water. If these rates were increased by an additional 25%, the overall deficit for these counties would be reduced by 75,000 acre-feet in 2040 and by 200,000 to 300,000 acre-feet between 2060 and 2100. If these rates were increased by an additional 50% (assumes 100% of the reclaimed water would be used for drinking water after 2040) the overall deficit would be reduced by 175,000 acre-feet in 2040 and by 450,000 to 550,000 acre-feet between 2060 and 2100. The vast majority of the deficit reductions would occur in Maricopa, Pima, and Pinal counties.

While increased use of reclaimed water for drinking water purposes would reduce the supply deficit, it would not eliminate it entirely. More importantly, however, it is highly unlikely that 100% of the effluent produced in the Eight County Area could actually be reclaimed and used for drinking water purposes. Currently the vast majority of reclaimed water is distributed for agricultural and industrial uses, and as a supply for turf and plants in residential, commercial, and municipal landscaping. In the future, there are likely to be more opportunities to use reclaimed water as a drinking water source through underground recharge and recovery programs.

Even so, it is improbable that reclaimed water currently used for existing industrial and landscaping uses will cease or that all of the reclaimed water produced in the future will be used entirely for drinking water. Reclaimed water will continue to be used for agricultural, industrial, and fish and wildlife uses in certain areas of Arizona. Residents of Arizona are likely to expect that turf and other landscaping amenities will continue to be included as part of common areas and open space for residential, commercial, and municipal land developments. These uses would presumably continue to be irrigated with reclaimed water rather than other sources. Furthermore, more expansive landscaping may prove necessary to counteract the heat island effect associated with higher density and more expansive urbanization that will arise with the projected significant population growth within the Arizona Sun Corridor.

Additionally, it is reasonable to expect that a portion of the reclaimed water stored underground will be used to firm in-state surface water supplies affected by drought. Consequently, greater use of reclaimed water alone will not provide a long-term solution to the water supply shortfall affecting the Eight County Area.

The other in-state option that could be considered to address the water supply shortfall would involve the acquisition of rights to Colorado River entitlements (CAP and/or mainstem entitlements) and the delivery of that water to the Eight County Area. For purposes of this paper it is estimated that an additional 25,000 acre-feet of CAP water would be leased from Indian Tribes on a long-term basis (e.g., 100 years or more), which would be enough to satisfy the state's assured water supply requirements. This would bring the total amount of CAP water leased under long-term contracts to 179,000 acre-feet or about 27% of the Indian supply. Indian tribes may actually lease more than the 25,000 acre-feet in the future; however, the leases may be shorter in duration to accommodate the tribes' needs to eventually use CAP water on their reservations for various economic development purposes. Accordingly, the future leases of Indian CAP water would not provide a sufficient amount of water to address the water supply shortfall on a long-term basis. Future Indian CAP leases would, however, provide another option to firm municipal surface water supplies used in the Eight County Area.

In terms of mainstem Colorado River entitlements, for the purposes of this paper, it is assumed that none of these supplies would be transferred on a long-term basis for use by municipal water providers in the Eight County Area. The legal authority to transfer mainstem Indian entitlements away from the reservations is unclear, although more definitive authority may be established in the future. The arrangement under which mainstem Indian entitlements would be considered for "transfer" to municipal providers in central Arizona would likely come under a forbearance agreement. A forbearance arrangement would not actually be a permanent transfer, but simply an arrangement for one entity to discontinue use of its legal entitlement to water for a period of time while another entity uses it. Under the arrangement, the municipal provider would obtain access to the water and, assuming an arrangement could be made with CAP, have the water delivered into central Arizona.

However, some of the complex legal issues associated with the "out-of-watershed" transfer of agricultural water from in-state sources may limit the extent to which mainstem Colorado River entitlements are used in central Arizona. For example, in a time of drought, when CAP entitlement holders would normally be authorized to receive a portion of any unused mainstem Indian entitlements, those holders are likely to adamantly object if the water is unavailable to them because of a forbearance arrangement that resulted in the water going to a non-CAP contract user. In anticipation of such problems, it is likely that any forbearance arrangement would contain provisions that required the user of the Indian entitlement to possibly relinquish the use of the water during times of drought. Consequently, most, if not all, mainstem Colorado River forbearance arrangements would not be reliable to sustain future municipal uses in the long-term. However, these arrangements would be useful to firm Arizona's junior priority Colorado River entitlement and its in-state surface water supplies.

In terms of non-Indian mainstem entitlements, there is likely to be significant resistance to permanently transferring these supplies away from the Colorado River region because they will eventually be used in Yuma, La Paz, and Mohave counties to supply future municipal and industrial demands. Additionally, there are unlikely to be large scale programs to transfer conserved non-Indian agricultural mainstem water to central Arizona because of the same legal impediments discussed above that impact arrangements to forbear Indian mainstem entitlements. Thus, non-Indian mainstem entitlements, whether in whole or in part (conserved water), would not be a dependable solution for the water supply deficit in the Eight County Area. Instead, as with Indian forbearance arrangements, conserved water could serve as a source to firm Arizona's in-state surface water supplies and its junior priority Colorado River entitlements.

In summary, each of the in-state options individually is insufficient in volume and in reliability to satisfy Arizona's long-term water supply needs for the Eight County Area. Collectively, with careful management, these supplies might be able to satisfy a good portion of the water supply shortfall anticipated to occur through 2040. Beyond 2040, Arizona would still require additional water sources from outside the state to satisfy its projected municipal demands.

B. Out-of-State Options

One out-of-state option Arizona could consider to augment the state's water supply would be to import water from the Columbia River Basin via the Colorado River Basin. There is a significant amount of water that could be imported from the Columbia River Basin into the Colorado River Basin and a favorable climatic pattern to help support the transfer program. Recent research concerning the location of the Polar Jet Stream and Pacific Ocean water temperatures over the last three decades has shown that when the Pacific Northwest is wet—i.e., has abundant precipitation and runoff—the Southwest is dry, at least during the El Niño/La Niña cycle.[42] This research also shows that the converse is true. As a result, a water transfer program that would take water from the Pacific Northwest during wet periods (when abundant water is in the Columbia River system) and deliver that water to the Colorado River system during dry periods (when its vast reservoirs are only partially full) would actually result in a more efficient utilization of water in both river systems. Such a program could significantly improve the reliability of Colorado River water supplies.

However, there is a myriad of difficult political, environmental, and legal issues that would have to be overcome to make this option viable. Politically, the Columbia River Basin states have historically been staunchly opposed to allowing any diversion of water out of the Columbia Basin. In fact, when the Colorado River Basin Project Act (Basin Project Act) was authorized, Senator Henry Jackson from Washington led an effort to get a moratorium provision added to the Basin Project Act's authorizing legislation that prevented the study of whether water from the outside the Colorado River Basin could be used to augment the Colorado River's supplies. While this moratorium has long expired, the views of political leaders and water, power, and environmental interests from the Columbia River Basin have probably not changed.

Furthermore, over the last decade, environmental issues associated with the preservation of salmon indigenous to the Columbia River system have placed additional constraints on the use of water in the Columbia River Basin. These constraints are focused on limiting diversions in order to provide more free flowing water in the Columbia River system. As a result, any plan to take water from the Columbia River Basin would now face significant environmental hurdles.

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42. *See* Kelly T. Redmond & Roy W. Koch, *Surface Climate and Streamflow Variability in the Western United States and Their Relationship to Large-Scale Circulation Indices*, 27 WATER RESOURCES RES. 2381 (1991); Earth System Research Laboratory, Composite ENSO, http://www.cdc.noaa.gov/ENSO/enso.comp.html (last visited Apr. 14, 2007); ENSO Composite U.S. Temperature and Precipitation, http://www.cdc.noaa.gov/ENSO/enso.comp.std.html (last visited Apr. 14, 2007).

Even assuming the political and environmental issues could be addressed, questions would remain about the extent to which Arizona could gain sufficient water from the Columbia River Basin to satisfy its long-term water needs.

Central to this uncertainty would be the structure of a compact among the Columbia River Basin states and Colorado River Basin states. Given Arizona's projected population and limited renewable water supplies compared to other Colorado River Basin states, Arizona's long-term water deficit is likely much more significant than those of any other Colorado River Basin state. Moreover, given its limited long-term Colorado River supply (its largest Colorado River allocation, CAP water, is currently regarded as the most junior supply on the Colorado River system), Arizona would need a disproportionately larger quantity of water from the Columbia River system than the other states. Arizona's demand for a proportionately larger allocation of Columbia River Basin water would also likely require it to assume a proportionately larger risk, and cost, associated with the diversion and use of water from the Columbia River system.

In summary, the complexity of developing a multi-basin state compact would require a significant negotiation effort among the states. Based on the history of negotiations among the Colorado River Basin states, it is uncertain whether a compact could be reached that would be satisfactory to Arizona. Given all of these factors, it is highly unlikely that Arizona could rely on imported water from the Columbia River Basin to satisfy its long-term water needs. However, a narrowly focused importation program that would take water from the Columbia River during wet periods in the Pacific Northwest when sufficient water was available for both salmon and importation might provide a good solution for the Colorado River Basin states to firm their supplies during drought periods.

Another option that could potentially provide Arizona with access to a significant quantity of renewable water would be an exchange arrangement with California involving Pacific Ocean water and Colorado River water. Under this proposal, Arizona would develop a freshwater supply by desalinating Pacific Ocean water for delivery to California—Metropolitan Water District ("MWD") and San Diego County Water Authority ("SDCWA")—in exchange for a portion of California's Colorado River entitlement. Arizona could potentially gain access to as much as 1,000,000 acre-feet of Colorado River water if it could provide a full replacement supply to MWD and SDCWA for their current and recently proposed Colorado River supplies, and also incorporate into the exchange additional quantities of conserved water that MWD and SDCWA are both contemplating developing in the future.

The advantages of this proposal are that it is a relatively straightforward concept, it would produce a drought-proof water supply for exchange with California, and it would not impact other states with Colorado River allocations. The potential limitations of this concept are the feasibility of desalinating 1,000,000 acre-feet of ocean water per year along the southern California coast as a supply source to exchange with Arizona, and the interest of California to do the exchange. With respect to the former, at the present time southern California water interests are contemplating developing eight desalination plants with the combined capacity to produce nearly 336,000 acre-feet of freshwater per year.[43] However, one of the more significant issues that must be addressed in the desalination planning process in California is finding acceptable sites for desalination plants. While the current proposed plants appear to be located in suitable areas, given the interests of southern Californians to preserve their ocean front properties, it may be very difficult to find acceptable locations in the future, especially if the plant is designed to produce water to trade with Arizona.

The latter issue, however, is even more problematic. California's current interest in developing desalination plants along its coastline stems from its immediate need to develop additional water supplies for its growing population, to improve the reliability of its existing water supplies, and to provide water for environmental uses.[44] Arizona's need for additional water is still many years away. Consequently, it is likely that by the time Arizona is prepared to trade desalinated water for a portion of California's Colorado River entitlement, California will have very little interest in trading because it will have already developed the sites to desalinate seawater along its coastline for its own needs. Additionally, to serve its future population, California will likely develop more plants or expand existing facilities on its own, rather than allowing Arizona to develop or expand plants to trade desalinated water with California for Colorado River water. Lastly, there are no indications that MWD will be interested in shutting down its Colorado River water delivery system to accommodate Arizona's need for additional water via an exchange for desalinated water.

A more promising and farsighted alternative to explore for developing a new source of renewable water would be an exchange of desalinated water with Mexico. Under this arrangement—an Arizona-Mexico Water Augmentation Consortium ("Consortium")—Arizona, working with the United States and Mexico, would desalinate seawater from the Gulf of California and provide the freshwater to Mexico in exchange for Mexico's allocation of Colorado River water. Currently, the majority of Mexico's Colorado River water is used for agricultural purposes. Depending on the location of the desalination plants and the infrastructure to deliver water to Mexico's agricultural areas, the Consortium could be expanded by exchanging additional desalinated water with California agricultural water users for a portion of their Colorado River entitlements.

The Consortium has multiple advantages over other options. Like the Arizona and California water exchange, it is a straightforward alternative that would produce a drought-proof water supply without impacting other Colorado River Basin states. However, unlike California, Mexico would likely have a significant interest in working with the United States and Arizona to facilitate development of desalination plants in the region. Mexico has a strong interest in improving the quality of water used in northern Mexico. At present the quality of Colorado River water provided by the United States to Mexico is a serious concern

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43. *See* HEATHER COOLEY, PETER H. GLEICK & GARY WOLFF, PAC. INST., DESALINATION, WITH A GRAIN OF SALT: A CALIFORNIA PERSPECTIVE 35 (2006).

44. *See id.* at 2.

to Mexico because it adversely impacts farming in northern Mexico.[45] Under this exchange arrangement Mexico would receive better quality water than it now receives from the United States. Another advantage of the exchange is that it would provide Mexico with an opportunity to develop a new source of drinking water for northern Sonora and possibly northern Baja California. In these areas of Mexico, there is a significant need for additional drinking water supplies.[46] By working jointly with Mexico, Arizona and the United States could help Mexico solve this critical problem. Still another benefit of the Consortium would be the potential for further regional economic development for Arizona and Mexico.

The potential limitation of this desalination/water exchange arrangement is the feasibility of desalinating sufficient freshwater to exchange with Mexico to meet Arizona's long-term municipal water supply needs. One of the frequent criticisms of desalinating seawater is that it costs more to produce when compared to the costs of existing drinking water supplies. Many factors influence the cost of desalinating seawater to produce freshwater, including (1) plant capacity, (2) feed water quality, (3) pretreatment needs, (4) the type of desalination process, (5) the energy supply, and (6) financing costs.[47] In general, because of economies of scale and assuming all factors being equal, larger plants tend to be less expensive to operate than smaller plants.[48] With current reverse osmosis technologies, reported costs per acre-foot for smaller plants (<1 million gallons per day or 1,000 acre-feet per year) typically exceed $1,800 per acre-foot, while larger-size plants (>10 million gallons per day or 11,000 acre-feet per year) range from $500 to $1,200 per acre-foot.[49]

The single largest cost component associated with the desalination process is the cost of energy. By co-locating a power plant and a desalination plant the energy cost for treating seawater would decrease significantly. Additionally, as new treatment technologies are developed, the overall cost to desalinate seawater is expected to decrease even further.[50] The cost of desalinating seawater to agricultural use standards is expected to be lower still.

While desalinated seawater is more costly than existing drinking water supplies, it is important to remember that the cost of current drinking water supplies are relatively low because they are derived from water sources secured more than 50 to 100 years ago. Given the limited availability of renewable water supplies in the Southwest and the environmental constraints associated with developing those supplies further, the costs for water produced from the next

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45. *See* U.S. Dep't of the Interior, Colorado River Basin Salinity Control Program—Overview, http://www.usbr.gov/dataweb/html/crwq.html (last visited March 29, 2007).

46. Dennis Small & Paul Gallagher, *Produce Water, or Fight Over It, Is the Real Issue in the West*, EXEC. INTELL. REV., Oct. 15, 2004, at 53.

47. SHAHID CHAUDHRY, CAL. ENERGY COMM'N, UNIT COST OF DESALINATION 2, *available at* http://www.owue.water.ca.gov/recycle/desal/Docs/UnitCostofDesalination.doc (last visited Apr. 25, 2007) (report on meeting with Metropolitan Water District).

48. *Id.*

49. *Id.* at 4–5; Shahid Chaudhry, Unit Cost of Desalination 2 (July 30, 2003), *available at* http://www.owue.water.ca.gov/recycle/desal/Docs/UnitCostDesalination.pdf.

50. *See* COOLEY ET AL., *supra* note 43, at 44–45.

generation of water sources are undoubtedly going to be much greater than current water costs. In effect, Arizona and other southwestern states have already picked the "low-hanging fruit" when it comes to water supplies. In the future, we all will have to go "higher in the tree" for our drinking water supplies.

Another area of criticism regarding desalinated water technology is the environmental concern relating to the disposal of the salt brine generated from the desalination process and the possible impingement and entrainment of marine organisms in a desalination plant's intake pipes.[51] While these issues have been mentioned by opponents of desalination plants, there has not been significant research on either issue to fully understand how much they impact the environment, if at all, and further, how the impacts, if any, might be monitored and mitigated.

On the other hand, there are several potential environmental benefits to desalinating seawater from the Gulf of California. As discussed previously, under this proposal, the desalinated water would significantly improve the quality of water being used in Mexico for farming. This water is also used for various domestic uses and consequently would be a significant improvement for those uses as well. Additionally, some of the desalinated water could be used to replace the poor quality water being delivered to the Cienega de Santa Clara wetlands. This could improve the wetlands ecosystem and provide the wetlands with a more reliable, consistent quality water supply.

In summary, each of the out-of-state options could potentially produce a significant amount of water for Arizona to use to serve the state's projected population in the long-term. There are advantages and disadvantages of each alternative; however, the Arizona-Mexico Water Augmentation Consortium may be the most viable. While this alternative appears promising, there are still significant economic and environmental feasibility issues that need to be addressed. Fortunately, Arizona has some time to evaluate these issues to determine whether a consortium with Mexico could work.

VII. CONCLUSION

Because of foresight and planning by Arizona's past leaders, the quantity of renewable water supplies, including renewable groundwater, across most of Arizona is sufficient to sustain the current population.[52] Within twenty years, however, assuming Arizona's population growth continues as projected, the municipal water demand in most counties of the state will reach or exceed the limit of the available renewable water supplies. Increased levels of water conservation and reuse of reclaimed water, together with increased groundwater pumping and

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51. *Id.* at 6.

52. There are a few locations in several counties—all rural, with increasing population, limited in-state surface water sources, and no current access to Colorado River water—where the currently available renewable water supplies are insufficient to supply the current population. In these areas, municipal providers are pumping groundwater at rates that exceed recharge to make up the shortfall in renewable water sources. In order for these areas to continue to serve their projected population, they will need to obtain additional renewable water supplies in the very near future.

some agricultural-to-urban water transfers, will provide a short-term solution to offset the renewable water supply deficit. In the long-term, however, Arizona will need to identify and implement a permanent solution to augment the state's renewable water supplies to sustain its anticipated long-term population. Similar to the state's requirements for municipal providers in AMAs, the state's solution should provide its citizens with an assured water supply for one hundred years or more. Given the state's potential population growth over the next century, Arizona could need as much as 1,000,000 to 1,500,000 acre-feet of additional water.

As might be expected, the alternatives available for developing up to 1,500,000 acre-feet of water over the next one hundred years are limited. The various in-state options include greater use of reclaimed water and transfers of agricultural water rights to urban areas for municipal use. As noted earlier, these options provide a good solution for bridging the renewable water supply shortfall in the short-term, but they are insufficient to sustain the expected municipal demand in the long-term. The out-of-state options include transferring water from the Columbia River Basin into the Colorado River Basin, and trading desalinated ocean water for Colorado River water with either California or Mexico. While importation of Columbia River water could be helpful in firming Colorado River supplies during drought periods, the political, environmental, and legal issues associated with such a transfer are extremely complex, making this option impractical as a long-term solution to augment Arizona's water supplies.

The seawater desalination/water exchange options are more straightforward to implement and would produce a drought-proof water supply. Unfortunately, California's own long-term water needs and the limited desalination sites along southern California's coastline make an exchange of desalinated seawater by Arizona for California Colorado River water unworkable. On the other hand, Mexico's interest in obtaining a better water supply for its agricultural uses and its own needs for drinking water supplies make it a more suitable partner for Arizona to trade for additional Colorado River supplies. While there are questions about the feasibility of desalinating the quantity of water needed by Arizona over the next one hundred years, Arizona and Mexico have time to explore the options and to determine the most feasible method to accomplish the exchange. Additionally, the technology and costs of producing freshwater from seawater, and the methods of minimizing or mitigating environmental concerns, are likely to improve significantly in the near future, and in the long-term, as the interest in desalinating seawater continues to grow and grow.

Even though Arizona has time to prepare for its future water needs, past experience shows that large water supply projects, e.g. the CAP, take many years to plan and develop. Accomplishing an exchange with Mexico using desalinated water from the Gulf of Mexico will require a concerted, coordinated effort among Arizona, Mexico, and the United States. The Arizona–Mexico Commission, chaired by the Governors of Arizona and Sonora, Mexico, could provide the forum to initiate these discussions. Concurrently, Arizona will need to identify a method for planning the project—including financing, construction, and management. Given the projected widespread need for water across most of Arizona and the importance of such a program to the state's future, the best approach might be the creation of an Arizona Water Authority to oversee Arizona's portion of the Consortium. Such an authority would be governed by qualified water resource engineering and business leaders appointed by the Governor and would need broad-based authority to perform all of the necessary functions to deliver water to municipal water providers within Arizona.

Today's Arizonans are the beneficiaries of the vision and thoughtful planning of past leaders. Arizona is one of the fastest growing states in the country. Its climate provides a relatively easy lifestyle and its low risk of natural disasters make it a very desirable place for people to make it home—on both a temporary and permanent basis. To ensure that the quality of life enjoyed by its citizens today is preserved for future generations, Arizona's current leaders must begin to plan for the development of additional water supplies.