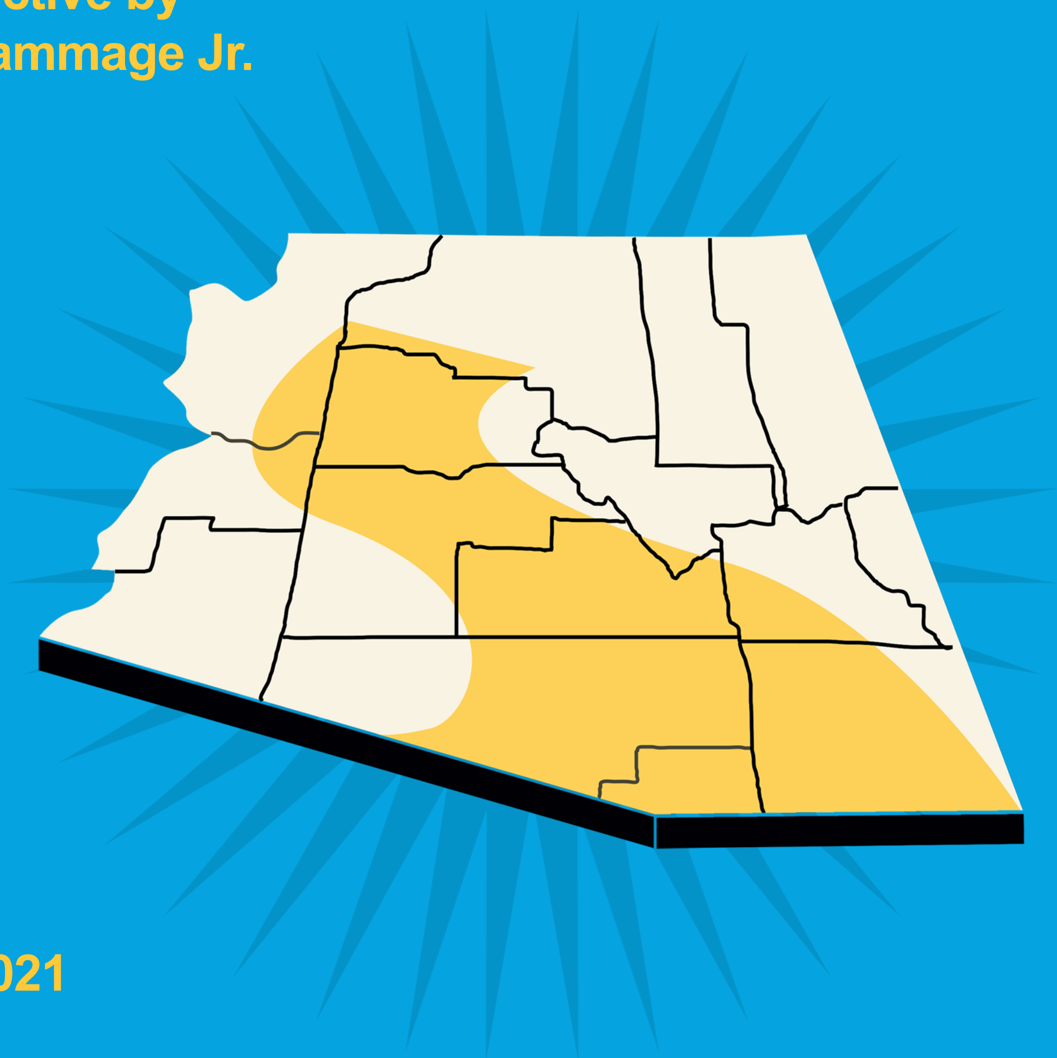
Return to Watering the Sun Corridor

A Perspective by
Grady Gammage Jr.



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Kyl Center for Water Policy
at Morrison Institute
Arizona State University

Forward

Kyl Center for Water Policy

This paper was originally prepared for publication in early Spring 2020. The intent was to revisit the methodology the lead author, Grady Gammage Jr., originally used in Morrison Institute's 2011 report, *Watering the Sun Corridor*, with updated statistics and analysis. He expected to follow it up with live presentations and discussions of the conclusions.

Then the Covid-19 pandemic hit. Live presentations evaporated, more pressing concerns intervened and issuing the paper was delayed. And of course, in the meantime, the challenges, controversies and dilemmas of Central Arizona's water situation have moved forward.

But this update is still relevant, so we have elected to proceed with publication with only minor changes from the draft as it stood last spring.

As noted in the report, Gammage's approach is a very high-level attempt to balance water supply and demand in the Sun Corridor. Because it expressly ignores the myriad legal, jurisdictional and physical challenges, it is an overly simplistic analysis, as Gammage himself admits. Nonetheless, it may prompt big picture thinking about the future and it is a first step to responding to the frequently asked question, "Does Arizona have enough water for future growth?"

The report takes a novel approach to answering this question: Realistically quantify the region's future annual renewable water supplies and divide by a conservative estimate of future per capita annual demand. The quotient is the Sun Corridor's future "population capacity."

Gammage doesn't offer the population capacity figure as a growth aspiration. To the contrary, he wants it to spark discussions about what kind of growth the region should aspire to. Should people in the Sun Corridor worry that all local agriculture might give way to urban development? Or should we try to reserve some quantum of water for farming? Should we have exchanges that enable freer movement of supplies from user group to user group? Are there tribal water rights holders who would be willing to enter into new transactions to make some of their water available for urban growth or other uses? Are some areas better suited to growth than others?

These questions are important, but they are just the first step. Water rights, entitlements and transactions are freighted with limitations and considerations that inject complexity into any proposal to change the way water is allocated. Behind every surface water right holder is a junior user who claims first dibs on any water the senior user leaves in the system. The older Sun Corridor cities and main-stem Colorado River water users have made big investments in long-term renewable water supplies and have sound reasons to defend policies that protect those investments. Tribal water rights settlements are the product of hard-won compromise among willing parties, and changes in the terms of those agreements risk upsetting a carefully struck balance.

As a severely limited and essential resource, water is the gas and the brakes of Arizona's prosperity and well-being. The state faces new and difficult challenges as we cope with reduced supplies from the Colorado River (and possibly other surface water systems), greater demand for groundwater, and unsettled water rights claims throughout the Sun Corridor and much of the state. While “watering the Sun Corridor” is, as Gammage says, about choices, it is also about conflict, costs, creativity and compromise.

In contrast with the original, the updated report’s conclusions strike a note of urgency. The horizon for serious limitations to Central Arizona’s continued growth looms ever closer. Gammage himself says: *“At current growth rates and based on current practices, we’ve got about a decade left. And in the scheme of water resources, a decade is the blink of an eye.”*

There are adaptive responses the region can make to shift this horizon. Additional efficiencies, new forms of reuse and different development patterns can all be part of the solution. For decades, many water experts have looked to declines in agricultural demand within the region as another piece of the puzzle. As mentioned in the report, some development interests are now looking to importation of additional Colorado River water to Central Arizona as a piece of the solution, leading to serious pushback from people in Western Arizona.

Indeed, Gammage himself represents a party in one such proposed transfer, from GSC Farms in Cibola to the Town of Queen Creek. That transfer was recommended for approval by the Arizona Department of Water Resources in September of 2020, but the amount of transferrable water was decreased by 50%. Based on subsequent evaluation of development opportunities in Cibola Valley, ADWR has concluded that “it is suitable for GSC to retain 50 af/yr . . . for future consumptive uses,” and transfer as much as 2033 AF/year to Queen Creek. ADWR’s recommendation will go next to the U.S. Secretary of the Interior for consideration. The actual amount which is transferrable may be further modified.[1]

Any opinions expressed in this report are those of the author and not the Kyl Center for Water Policy. The mission of the Kyl Center is to promote informed public dialogue on critical water issues in Arizona and the West. We hope that this update to *Watering the Sun Corridor* will do just that.

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Return to Watering the Sun Corridor

A Perspective by Grady Gammage Jr.
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A lot has flowed under the bridge since the Morrison Institute issued *Watering the Sun Corridor* in August of 2011. That report was an attempt to explain to a general audience how the water systems of urban Arizona work, and how those systems could support a large population. At that time, thinking about the spine of cities stretching from Prescott, through Phoenix and Tucson, to Nogales represented a relatively new geographic definition, stemming from a 2008 Morrison Institute report, *Megapolitan: Arizona's Sun Corridor*.

Watering the Sun Corridor addressed the understandable concern that urban Arizona might be "running out" of water. The report quantified and aggregated the water inputs available to the geography and sought to balance those inputs against demand and anticipated population growth. The conclusion then was that even in the face of climate change, the water supply for the Sun Corridor was relatively robust and could support continued future growth.[2] In order to keep growing, however, the report suggested that tough choices would be necessary about the nature of our desert lifestyle, issues of urban form, landscaping, the natural environment and the role of agriculture.[3]

As the principal author of *Watering*, I hoped it would touch off a lively debate about the trade-offs between different water uses and how our society of desert dwellers should prioritize such choices. That did not happen. The report received some criticism as presenting too rosy a picture in not calling for draconian growth restrictions; as being a rationalization for continuing "business as usual." Others read it with a sigh of relief: "I guess we'll be OK." The hope of producing a more subtle and sophisticated conversation about supply and demand did not materialize.

Ten years later, today seems like a good time to reflect back on *Watering*. The world, and the Desert Southwest, seem like different places.

- Population projections have been revised to account for slower growth.

- The drought in the Southwest has continued, with the 2020 summer "monsoon" being non-existent.
- Publicity about the water situation in the West has been widespread, increasing public awareness and a sense of crisis.
- Climate change is accepted as reality by nearly everyone, and may be more dramatic than was thought in 2011.
- The Colorado River system—Arizona's largest renewable water supply—has come under increasing pressure, forcing the "basin states" to adopt the widely heralded Drought Contingency Plan (DCP).
- Tension between water "haves" in the Sun Corridor and potential "have nots" in rural Arizona has become more evident.
- Water prices have increased and some cities have adopted new restrictions on use.
- Farmers have felt increasingly beleaguered, facing what some have described as a "cataclysm" in Central Arizona.

This essay is not a new edition of the original report. The explanation there of how the water systems work remains unchanged. Many people contributed to *Watering the Sun Corridor*, both with research and financial support. This is not as collective an effort. It is, rather, a limited reflection on what has happened over the last few years and how to integrate that thinking into the big picture of the Sun Corridor's future.

One other change: In 2014, the Kyl Center for Water Policy was established within the Morrison Institute. The Center has focused the discussion of these issues and been instrumental in helping revisit *Watering the Sun Corridor*.

Is It Time to Panic?

Over the last decade, publicity about the western drought and the future of the arid West has been relentless. In his 2011 book *Bird on Fire*, NYU Professor Andrew Ross labeled Phoenix "the world's least sustainable city" because of the low density, resource intensive nature of post-war cities, particularly in transforming the landscape by moving water.[4] The same year, the same publisher (Oxford University Press) issued William deBuys' *A Great Aridness*, predicting that climate change would likely send places like Phoenix and Las Vegas back into the desert from which they came.[5] Most entertainingly, Paolo Bacigalupi's *The Water Knife* (2015) painted a picture of a dystopian future West in which Nevada, Arizona and California engage in open, bloody hostility.[6]

In 2010, the *New York Times* headlined a study predicting that western water scarcity might result in default on water bonds in cities like Phoenix. In 2015, the same paper predicted: "Still, Arizona is in dire straits. … [C]alculations based on Arizona's own water accounting suggest that demand could outpace its existing water supply in less than a decade."[7] *The Guardian* in 2018 asked "Plight of Phoenix: How long can the world's 'least sustainable' city survive?"[8] In the middle of 2015, *Slate* wrote: "Yes, the drought is bad in California. It is going to be much, much worse in Arizona."[9] At about the same time, the *Los Angeles Times* predicted that "cities like Phoenix might have to begin reusing wastewater and even capping urban growth."[10] Later, in 2015, *Slate* used the elevations in Lake Mead as a proxy for the crisis: "As Lake Mead hits record lows and water shortages loom, Arizona prepares for the worst."[11] *The Arizona Republic* did the same in 2018: "At water-starved Lake Mead and Lake Powell, 'the crisis is already real.'"[12] In 2017, *Vice* opined: "Phoenix will be Almost Unlivable by 2050 Thanks to Climate Change."[13] And, in 2019, the Sierra Club magazine ran a feature warning that "time is running out" for Phoenix to take steps to adapt to the coming climate crisis.[14]

California's very visible drought from 2011 forward drove much of this publicity. A number of the commentators appear to have "discovered" that the Central Arizona Project (CAP), since its inception, has been a junior right holder on the Colorado.[15] The increasing bathtub ring at Lake Mead, and Las Vegas digging a new lower intake, seemed to presage a “dead pool” in the reservoir. Of course, the fact that the Sun Corridor’s dominant city is named after a bird that periodically immolates itself clearly invites scrutiny.

When the Colorado Compact was developed by the seven basin states in 1922, the Lower Basin was allocated 7.5 million acre-feet (MAF) of water. For the next four decades, Arizona and California disputed how much water should be allocated to each of them, leading finally to the famous 1963 U.S. Supreme Court ruling in *Arizona v. California*, which confirmed the allocation of 4.4 MAF to California, 2.8 MAF to Arizona and only 300,000 acre-feet to Nevada. (Nevada had little population, limited agriculture and only touched the river at one point.) The Court’s ruling also affirmed Arizona’s contention that the waters of the Gila River (including its tributaries, the Salt and Verde rivers) did not count as part of the state’s 2.8 MAF.[16] The result was actually favorable to Arizona.

The perception that Arizona is worst off among the western states is wrong. There are a number of reasons why Arizona’s position among western states is among the best, not the worst:

- The junior priority has largely turned out to be a blessing rather than a curse. It made Arizona, and particularly the Sun Corridor, which is served by the CAP, take seriously the risk of shortage long before California.
- Because rainfall in Central Arizona is unpredictable and often sparse, water systems were designed with robust storage (both reservoirs and underground) and to bring water from distant sources. These hydraulic constructions smooth out a variable water supply.
- To get the federal government to fund construction of the CAP, Arizona was required to start regulating groundwater pumping beginning in 1980. The Groundwater Management Act has been a success, though not a panacea. But California didn’t enact groundwater management legislation until 2014.
- The Sun Corridor has been a great place to grow crops and is a good place to grow people. It has plenty of land, endless sunshine, and mechanisms to transport water. These water systems were largely built around agriculture, and about half the water in the Sun Corridor is still used to grow crops. As subdivisions replace farms, water use declines. This is different from Colorado, where people live on one side of the Rockies and farms and water are on the other; or California, where cities are on the coast and agriculture in the central valleys. Farming in the Sun Corridor faces a genuine crisis, but that does not necessarily translate into urban shortages.[17]
- Because of the risk of shortage and the junior priority, CAP, the Salt River Project (SRP) and the cities in the Sun Corridor started banking water underground nearly 15 years ago. Nearly 12 MAF have been banked in the aquifers, representing nearly 7.5 years of urban demand for the Corridor.[18]

Since about 2000, the Colorado River basin has been under extreme stress. This stress results from the coincidence of two factors: drought and a “structural deficit.” The structural deficit simply refers to the reality that the river is over-allocated. In a “normal” year, the U.S. Bureau of Reclamation releases enough water from Lake Powell to Lake Mead to satisfy the entitlements of California, Arizona and Nevada and half of the 1.5 MAF/year Mexico is entitled to under treaty with the United States. However, the Lower Basin system loses hundreds of thousands of acre-feet of water to evaporation and other system losses each year.[19] The standard operation of the river has called for about 8.2 MAF to be released from Lake Powell to flow into Mead.[20] This creates a shortfall, or "deficit," in the lower basin of around 1.2 MAF/year. Even without drought, this is not a sustainable condition. The recent years of drought exacerbate this condition and the result has been annual decline in the elevation of Lake Mead. When water levels fall low enough, the Secretary of the Interior declares a shortage. As junior rights holders, customers of the Central Arizona Project would absorb the shortage along with Nevada before California is impacted.

Arizona's risk is substantial. So, starting in the early 2000s, the state began lobbying for a fairer system that would entail smaller cuts over a longer period, leaving more water in the river system. Criteria for sharing anticipated shortages among the Lower Basin states were first adopted in 2007. In May 2019, all seven basin states and the federal government signed on to the much heralded Drought Contingency Plan (DCP). Arizona is both a principal contributor to the plan (agreeing to forego the largest share of water deliveries to maintain lake levels) and the principal beneficiary (since California agreed to share shortages rather than make Arizona take the entire hit).[21]

With the prospect of cuts in Colorado River supplies looming, Central Arizona farmers find themselves in a similar position to the state as a whole: They are in a "junior" position for CAP water to cities in the Sun Corridor. Their subordinate position was the result of renegotiating their contract rights when the CAP canal was completed but the price of the water was too high to be affordable for agricultural use. Central Arizona agriculture agreed to give up long-term contracts for shorter term deals at a lower price. At that time, it looked like there would be plenty of CAP water to be delivered to farms until about 2030, when urban growth might take most of the water. But higher priority municipal and Indian contractors took more of their CAP allocations sooner, and as a result of the structural deficit and the drought, the shortages are coming now, not in the distant future. That means farmers have recently sought financial assistance from the state to go back to pumping groundwater—not a long-term sustainable solution, but a cushion to a crisis that happened earlier than expected.

There is a clear message from the DCP experience: The future has arrived.

Reliable Water Supply

Defining water supply is harder than it sounds. One analysis of Maricopa County viewed supply in terms of rainfall, ignoring the reality that in significant parts of the U.S. "beyond the Hundredth Meridian" rain is less than 10 inches per year.[22] To citizens of Chicago, their water supply is obvious: A gigantic lake is *right there*. The potential for reusing effluent is often touted as "the next water supply."

Watering the Sun Corridor offered a particular, and in some respects relatively novel, take on defining water supply:

> *In this report, we will define the Sun Corridor's water supply as physical water inputs. These include rain, surface water that can be transported and made available, and the amount of pumped groundwater that is naturally replaced every year. Everything else—reservoirs (which we sometimes call "lakes"), effluent, artificial groundwater recharge, conservation—will be treated as management techniques.*

This view was controversial at the time, as it remains today. But the logic still remains—using water more than once, or foregoing human use to leave it in the natural environment—does not create more water, but rather stretches what water already exists. A number of Arizona cities will vehemently disagree, viewing increased use of reclaimed effluent as a principal source of water for growth. But another city can as easily argue that conservation should be viewed as new water supply, or that retiring grass from single family homes will produce a new bucket of water for the future. For purposes of this revisit, we will stick to the original proposition: Water supply is the aggregation of initial inputs to a water system; after that, it is all about stretching that supply.

The goal of this view is to suggest learning to live within our means. There are possible genuinely new sources of water. Ocean desalination off of Mexico or California and physical transport to Arizona, or in exchange for California water in Lake Mead, is often offered as the ultimate panacea. Occasionally, diverting water from the Pacific Northwest or the often-flooded Midwest are touted as other solutions. Iceberg towing does not seem to have gotten much mention lately. Of those "next buckets," only ocean desal seems likely, but it remains far off, expensive, and probably unnecessary for the foreseeable future.

The approach of aggregating all potentially available sustainable sources of supply particularly annoys the large class of managers, hydrologists and lawyers collectively (and affectionately) referred to as "water buffalo." The complex web of legal, jurisdictional and political restrictions around individual blocks of water makes movement from one use, or one entity, to another very difficult. This report ignores all that for purposes of providing a high-level look at the sustainability of the region.

Based on a variety of sources, the original report summarized the Sun Corridor water supply as seen in Chart 1.

Chart 1: 2011 Supply Assumption[23]

Salt Verde	800,000 Average AF/Yr
Other Surface Water	250,000 Average AF/Yr
Natural Groundwater Recharge	260,000 Average AF/Yr
Colorado River	1,500,000 Average AF/Yr
TOTAL	**2,810,000 Average AF/Yr**

One of the contributions of the original report was the attempt to quantify the "other surface water" supplies listed in Chart 1. This is a combination of rivers and creeks in all three of the Active Management Areas within the Sun Corridor.[24] Most of this water is not easily captured for urban use and may already be committed to other purposes. The largest single component is the upper Gila, which is used for irrigation outside of the Sun Corridor, and would be legally and politically very difficult to transfer. Upon reflection, it seems prudent to remove that approximately 100,000 AF/year from the calculus.

Recent data suggest further changes to these numbers. The "natural recharge" in the chart was calculated by ADWR for the Phoenix, Pinal, and Tucson AMAs. Today ADWR puts that number higher: 344,000 AF. The reason for this recalculation is not clear, but we will use the new number. An additional very significant adjustment in these numbers is also necessary today. The original report's Colorado River delivery of 1.5 MAF/year has long been the estimate of average CAP deliveries. The canal can, and has, actually delivered significantly more. But in light of the structural deficit, a lower assumption should be made. This is tricky, because there is no negotiated long-term solution on how to share the 1.2+ MAF structural deficit. Arizona will undeniably be expected to "suck up" a major share. The original report made no adjustment for the structural deficit, but simply relied on the CAP long-term estimate of deliveries.

It is not the goal of this report to predict, or even anticipate, what the long-term impact of the deficit might be. But some assumption is necessary. The reduction could conceivably be as much as 500,000 AF. Here we will use an arbitrary 300,000 AF cut to address the structural deficit. Any official long-term cuts in CAP supplies will be negotiated in the anticipated "reconsultation" process in which Colorado River water users from the seven Basin States and Mexico attempt to determine new management rules for the entire system. However, under the DCP, Arizona has agreed to take the lion's share of cuts and any agreement for permanent reductions would likely also require that Arizona take a disproportionately large cut. Even a larger reduction of 500,000 AF would protect supplies for cities and towns on the CAP, the highest priority users (along with Indian tribes) in Central Arizona.[25]

These two adjustments to the abstract definition of water supply are shown below:

Chart 2: 2020 Supply Assumption

Salt Verde	800,000 Average AF/Yr
Other Surface Water	150,000 Average AF/Yr
Natural Groundwater Recharge	344,000 Average AF/Yr
Colorado River	1,200,000 Average AF/Yr
TOTAL	**2,494,000 Average AF/Yr**

In *Watering the Sun Corridor*, following the calculation of aggregate supply, a climate change reduction of 15% was made, based on estimates from the National Oceanic and Atmospheric Administration and the U.S. Bureau of Reclamation (USBR) of projected declines in the Colorado River. This reduction was applied to the entire supply—not just the Colorado. Today, the 15% number still seems to be on the low end of projected average climate change impact. Recent U.S. Geological Survey estimates reduce the Colorado River flows by amounts ranging from 14% to 26% in one study, and by 19% to 31% in another.[26] For purposes of this update, we will drop the 15% reduction number that was used in 2011, and use 20%, 25%, and 30% potential climate change impacts. As before, we will apply the reduction to the entire supply calculation, not just to the Colorado.[27]

Even after almost another decade of climate science and debate, and even after a dramatic decline in Colorado River run-off, projecting a reliable "average" water supply is still full of challenges. Averages do not mean much when variation can be from 25% to 400% of "average." As the summer of 2019 descended on Arizona, the "lakes" were filling up, water managers were breathing easier, and the situation did not seem so dire. Then the 2019 summer monsoons failed to materialize. So, by fall, the press coverage of water issues was once again sounding panicky. This chronic short-term, knee-jerk response to long-term issues lies at the heart of misunderstandings about water.[28]

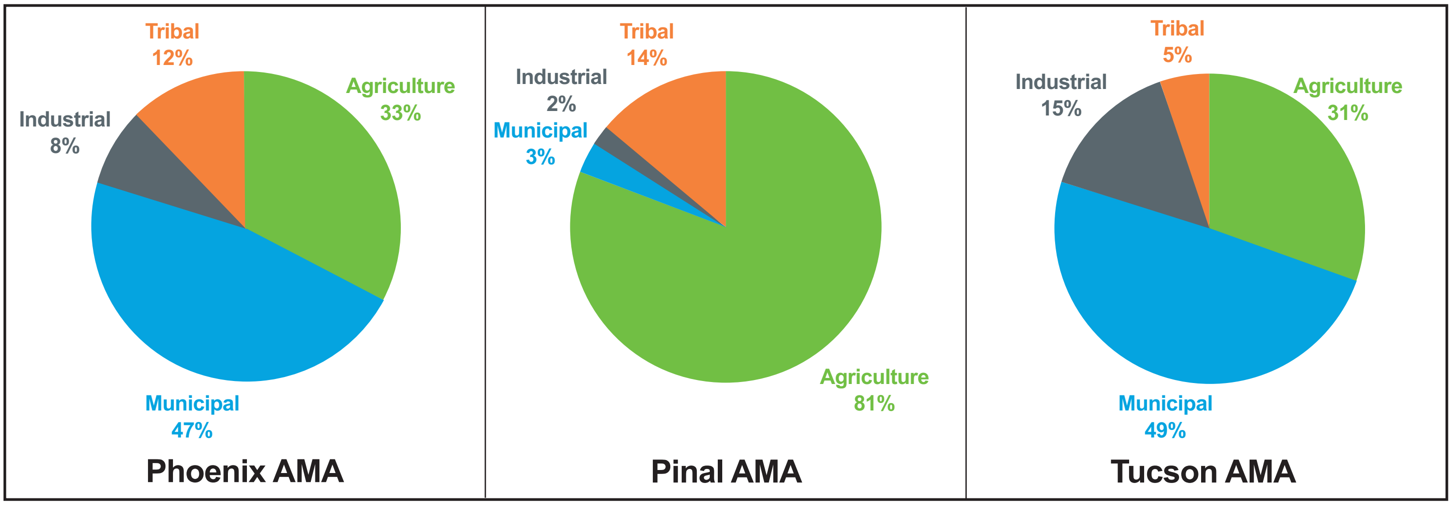
One of the most clearly predictable consequences of climate change is not a definable lessening of snowfall in the mountains; it is a more highly variable amount of snowfall. The average will quite probably fall over time and the term "average" will likely become even less meaningful. While 15% remains a supportable climate change assumption, in the post-DCP environment it seems prudent to also analyze a larger impact and more alternatives.

Chart 3: 2020 Supply Estimates (AF)

Climate Change Reduction	2,494,000
-20%	1,995,200
-25%	1,870,500
-30%	1,745,800

The clearest lesson of the attempt to quantify water inputs is the need for increased management flexibility to deal with increasingly variable supply. Building more big reservoirs presents daunting financial and environmental obstacles,[29] but increased groundwater banking should be standard practice in any years of abundance.[30] Creative water exchanges within the Corridor—as have been used between

Chart 4: Water Use by Sector (10-year average)[31]



Phoenix and Tucson, and between Indian tribes and cities—can allow water to move more freely as needed. Economic transactions in the form of water markets are another example.

The most significant way to support more growth based on the Sun Corridor's *existing* water supply is to shift agricultural use to urban use. This has long been regarded as the simple conversion to give us comfort. At the statewide level, it is an easy statement: More than 70% of Arizona's water is still used for farming.

For the Sun Corridor, however, this is no longer so simple. CAP supplies used for non-tribal agriculture cannot be counted on in the future and the farmers who have relied on CAP Non-Indian Agriculture supplies are turning to groundwater pumping. That pumping is not a long-term urban solution because the supply is finite. On the other hand, some tribes in the Sun Corridor have significant surface water dedicated for agricultural use. Shifting those supplies from farming to urban growth would involve complex legal and jurisdictional implications and, without question, obligations on the part of urban users to remunerate tribes for the use of that water. For this analysis, however, we will assume Indian agricultural water in the Sun Corridor represents a source of supply that could become available for urban use through voluntary transactions.

The "water inputs" definition includes using all the available water to satisfy all the available demand by careful management, storage, reuse and conservation. *Watering the Sun Corridor* used that definition of supply to derive a "carrying capacity"—a maximum sustainable population—for Arizona's urban core. That conclusion also must be re-examined.

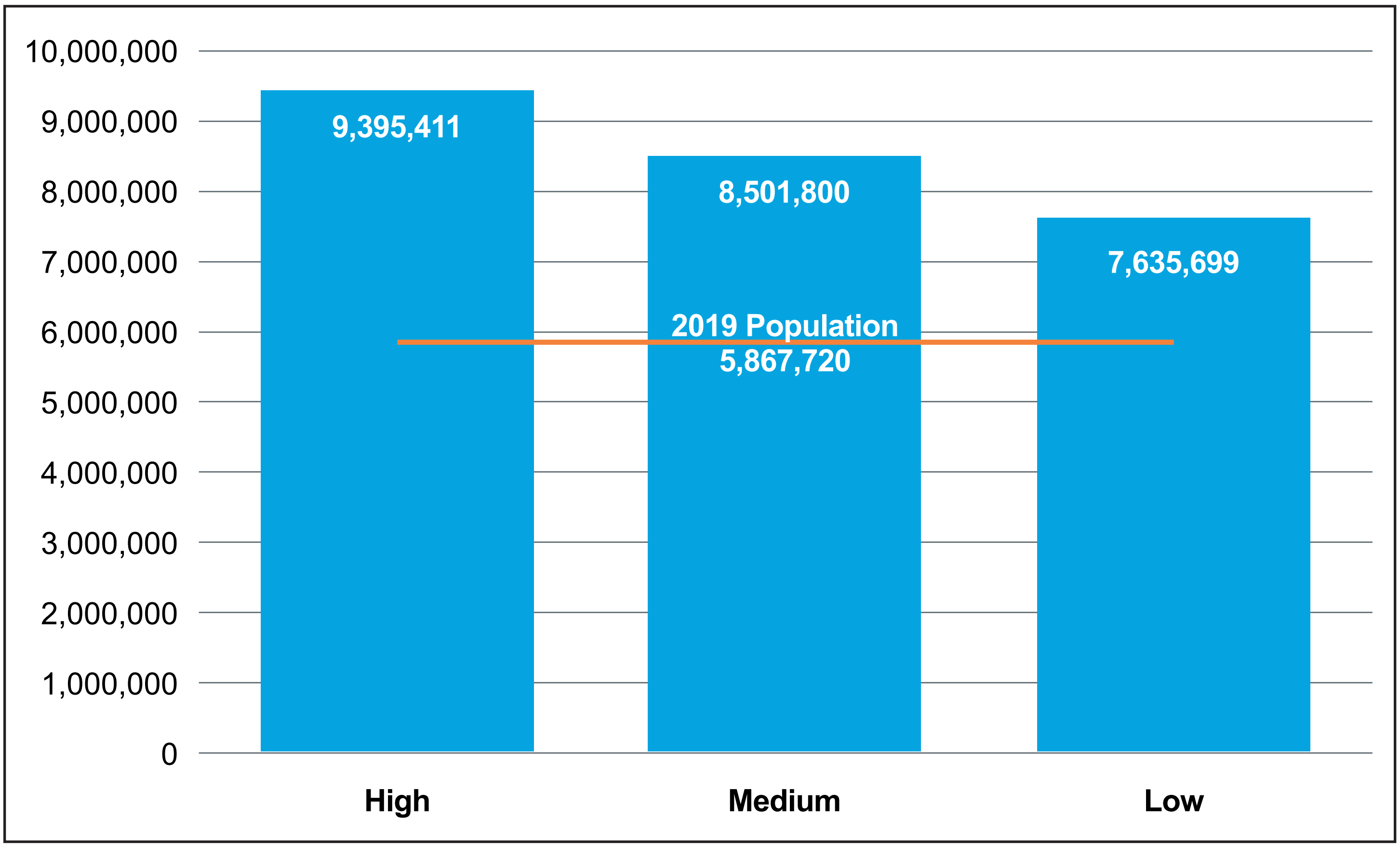
So How Many People Can the Sun Corridor Hold?

The ultimate punchline of *Watering* was a chart balancing urban water use against supply to roughly approximate the population capacity of the Sun Corridor. Reaching any such population horizon is fraught with risk. No precise calculation is possible—particularly not in a pluralistic, capitalist democracy which recognizes a "right to travel" as a constitutional matter. A high number will be unrealistically reassuring that there is nothing to worry about; a low number can engender near panic or dismissal as irrelevant. Even getting to any approximate "conclusion" requires multiple steps, with the risk of compounding mistaken assumptions.

The population capacity projections of the original report—and of the charts below—treat the Sun Corridor as a single geographic unit. This is wildly simplistic, and intentionally used only to provide some context for discussion. The reality is that five counties,[32] more than 40 cities, and dozens of water providers all have different situations. Some large Sun Corridor municipalities, like Phoenix, have vast, diversified and carefully managed portfolios of water supply to carry them through their projected build-outs. Many newer, smaller cities are much more dependent on a single supply and may already be overtaxed in coping with growth. And some small water companies teeter on the edge of mismanagement and bankruptcy. This analysis glosses over all of those critical differences. The Kyl Center is producing assessments to help understand some of these variations and issued a paper critiquing potential overuse of the Central Arizona Groundwater Replenishment District by some areas of the Sun Corridor.[33]

Back to the analysis of the overall Sun Corridor urban situation. First, it is worth revisiting the growth projections. In 2011, the "most likely" projection was a population of 9 million by 2040 in Maricopa, Pima and Pinal counties. Nine years later, the official projections are not too different. Given the passage of time, projections now run out to 2050, and look like this (see Chart 5):

Chart 5: Sun Corridor 2050 Population Projections[34]



The next step is to correlate the water supply conclusion with what kind of population can be sustainably supported. The 2011 report did this by seeking to derive a meaningful per capita water consumption number for the Sun Corridor's urban population based on existing trends. The report did this by splitting the uses within the Corridor into "urban" uses and "commercial agriculture." This remains a useful distinction. Urban use was intended to capture all water demand by the population of the Sun Corridor including indoor and outdoor use for houses, industry and commercial activity.

Traditionally, the Arizona Department of Water Resources (ADWR) has used "GPCD" (Gallons per Capita per Day) as a metric to measure urban water use and to compare water demand between active management areas or individual cities. But GPCD is a tricky statistic. Sometimes it includes only residential uses. By that metric, Phoenix currently hovers around 100 GPCD. ADWR's method, known as total GPCD, takes the total water deliveries by a municipality or private water company and divides that number by the population the entity serves. "Total GPCD" includes most commercial and industrial uses, but it does not capture users with their own wells, or flood irrigation delivered directly to homeowners.[35]

By the traditional ADWR method, Total GPCD has been steadily declining as residential and commercial use has become more efficient.

In the original report, the GPCD rates for the three AMAs in the Sun Corridor were falling through 2008. A comparison of residential GPCDs from 2005 to 2018 (see Chart 6) shows continued declines in the Tucson AMA, by

Chart 6: Residential GPCD Trends, 2005 to 2018[36]

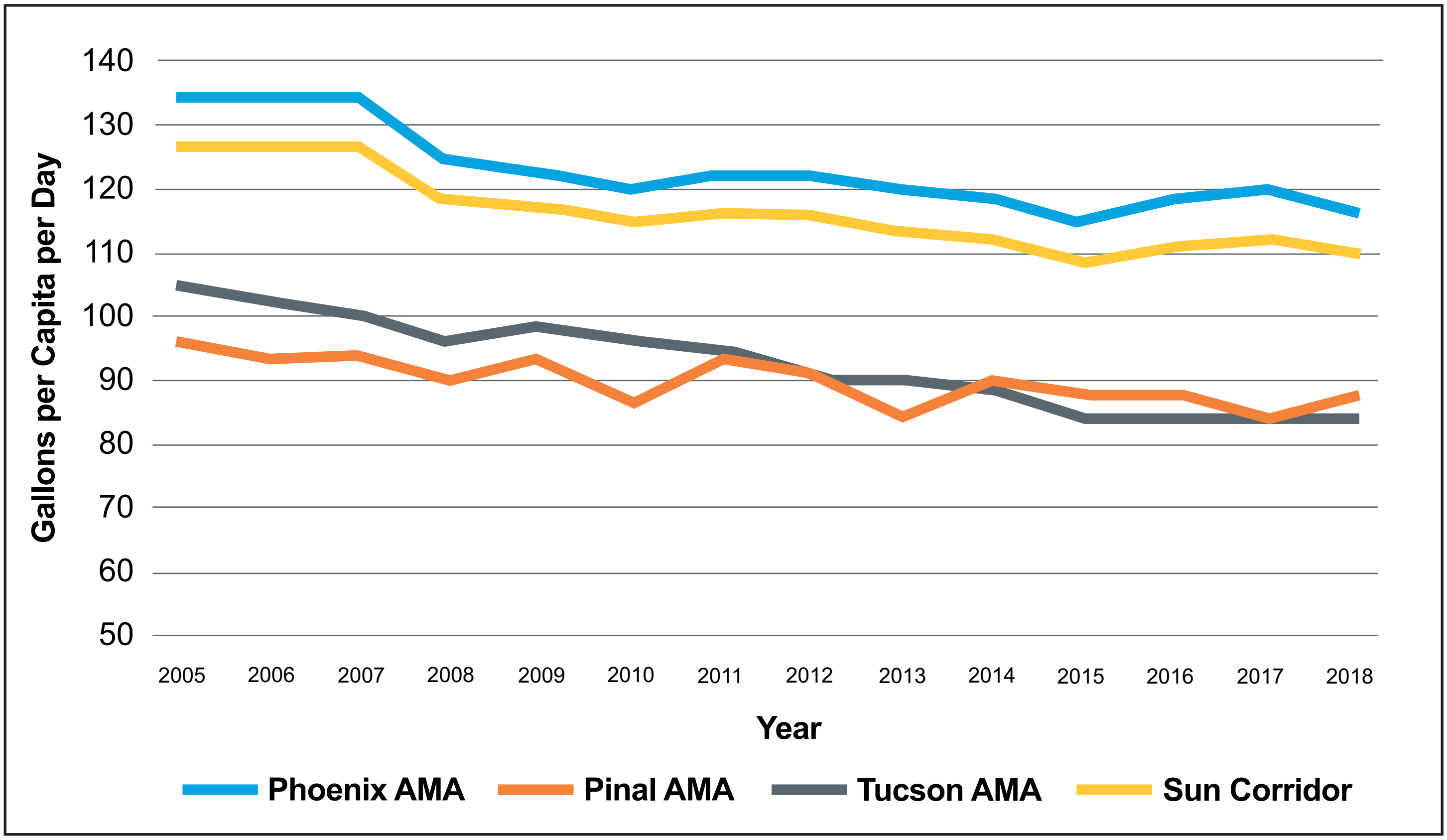
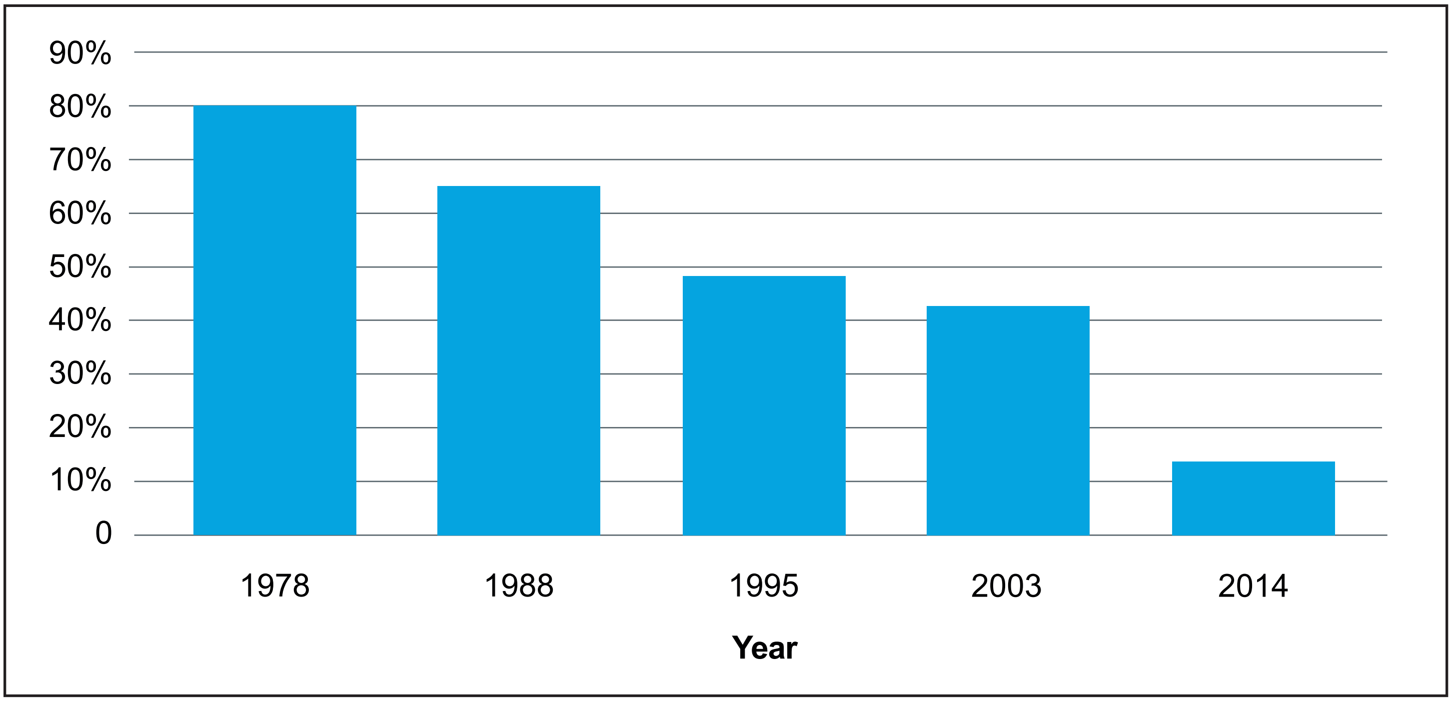


Chart 7: Phoenix Proportion of Grass or Turf as Majority of Landscape, 1976-2014 Estimates[37]



about 11%, and the Phoenix AMA, by 10%. Average GPCD in the Pinal AMA has held steady . Overall, the regional residential demand currently hovers just below 110.

Decline in GPCD is the result of numerous factors. Water rate increases have an impact on water use. Increased educational emphasis on conservation is significant. Smaller lots, newer houses, landscaping changes, retirement of inefficient fixtures, more multifamily development and fewer swimming pools all play a part. The most eventful trend for water use is the decline in turf lawns at single family homes. As Chart 7 shows, the city of Phoenix estimate is dramatic.

Unfortunately, the traditional GPCD statistics are not really a good proxy for all urban water use. Many aspects of water use correlate with population, and are subject to increasing efficiency and conservation. This is where the total GPCD statistics are useful. But there is an

Chart 8: Water Uses in the Sun Corridor

Per Capita Based (GPCD)	Non-Per Capita Based (Non-GPCD)
Municipal Residential Municipal Commercial	Sand and Gravel Mining Golf Courses Non-Golf Turf Parks Dairies Feedlots Other Industrial Non-PVNGS Power Generation Residential Flood Irrigation
Not Included	
Mining (other than Sand and Gravel) Commercial Irrigated Agriculture Indian Category Demand	

additional set of “urban” uses that do not track population growth as clearly but are still located in or near urban areas because of demand. Examples are most often businesses or entities that receive untreated water deliveries or have their own wells: factories, some golf courses or plant nurseries, sand and gravel mining and, in Maricopa County, residential flood irrigation.

Chart 9: Sun Corridor Urban Water Use Trends[38]

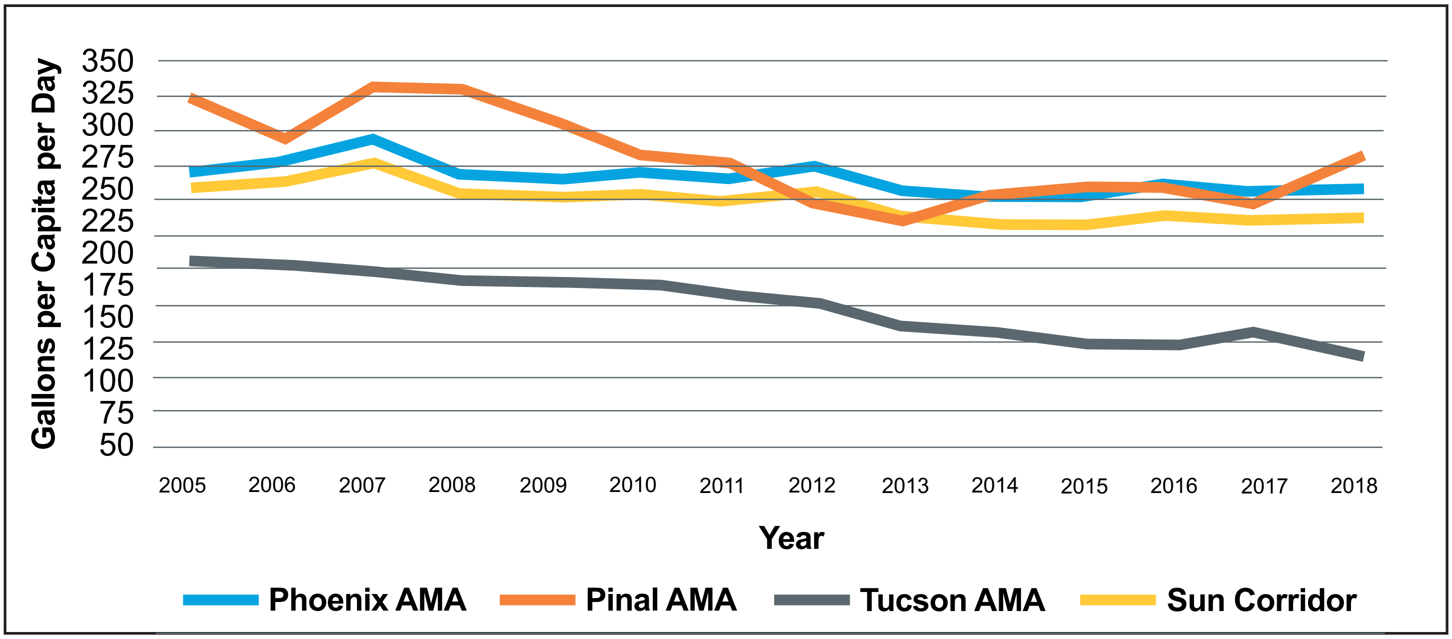
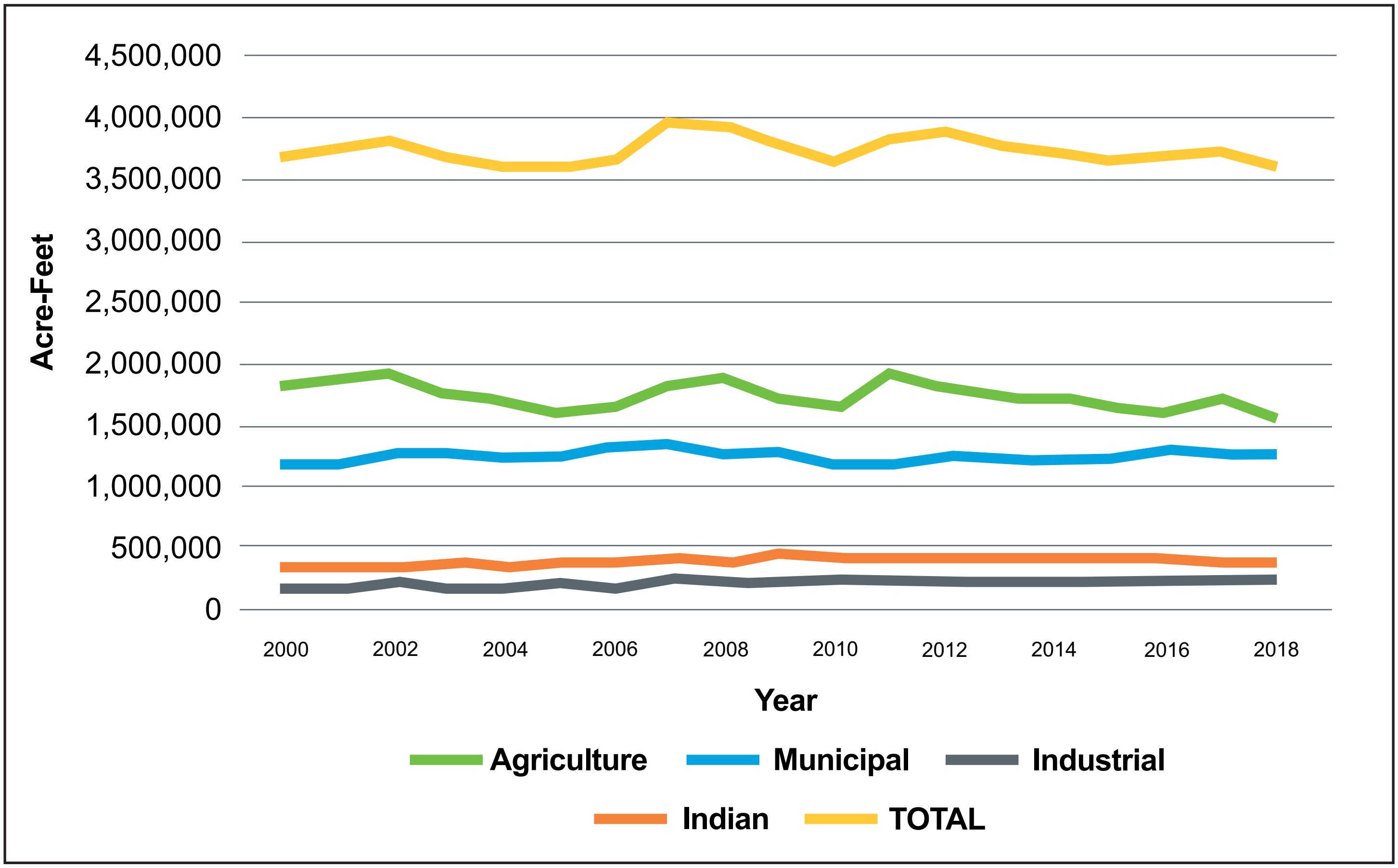


Chart 10: Sun Corridor Annual Water Use by Sector[39]



In the original report, these non GPCD but urban uses were accounted at 175,000 AF/year based on the best data we could find at the time. Today, the number appears to be about 189,000 AF/year (see Chart 10). This number might either increase or decrease over time independently of population growth. Because such changes are impossible to predict, we will add the 189,000 AF/year number into urban demand, but hold it constant.

If these additional urban uses are added into the total GPCD calculation, a much higher per capita rate of consumption results for the same population base. For example, using the more expansive view of “urban uses” suggests an “Urban GPCD” statistic between 250 and 300 gallons (see Chart 9). These higher numbers are a more accurate representation of current and future urban use.

These are complex statistics: For the sake of this analysis, we will assume continuing per capita consumption to be in the 200 gallon/day range. While GPCD continues to trend generally downward, we can reasonably expect a “levelling off” as water saving fixtures and appliances become ubiquitous and economic growth in the metro areas increases non-residential consumption. This potential trend deserves further research and monitoring.

In the original report, the commercial agricultural uses in the corridor were based on 2006 numbers. Today, the best recent data is from 2018. Chart 10 shows what the trends look like.

Since 2000, non-Indian agricultural water use has trended down, while municipal and industrial demand have increased gradually. Water use by Native American tribes has also gradually increased, in part as a result of the historic settlements of tribal water rights claims that enabled the Gila River Indian Community, the Tohono O’odham Nation and other tribes to make use of their water allocations. Notably, total water use has held fairly steady.

In 2011, the report estimated total urban use in the Sun Corridor at 1,295,000 AF/year. This was based on adding the 2011 estimated 175,000 AF/year non-GPCD urban use with GPCD use based on a population of 5 million and an average of 200 GPCD.[40] Continuing to use 200 GPCD at today’s population of 5.9 million would yield a total use of 1,321,770 AF/year. Since 2005, the average annual industrial demand for non-reclaimed water has averaged 189,000 AF/year.[41] This amount added to urban demand results in a total demand of 1,510,770 AF/year.

Today, several refinements to the chart seem warranted. First, to reflect the decreases in potable supply as suggested above to account for the structural deficit and climate change. Second, including a 150 GPCD target seems unrealistic, given that the Total GPCD for the Phoenix AMA remains well over 200. Accordingly, we will use 220, 200, and 175 GPCD.

Chart 11: 2011 Chart from *Watering the Sun Corridor*

	Water Supply		
	1,800,000 AF	2,000,000 AF	2,200,000 AF
Per capita use	**Approximate Population**		
200 GPCD (0.22 AF/yr)	8,182,000	9,100,000	10,000,000
150 GPCD (0.17 AF/yr)	10,588,000	11,765,000	12,941,000

Chart 12: Updated Population Sun Corridor Projections Based on Water Supplies

	30% climate change reduction	25% climate change reduction	20% climate change reduction
Total Supply	1,745,800 AF/yr	1,870,500 AF/yr	1,995,200 AF/yr
Municipal Supply*	1,556,800 AF/yr	1,681,500 AF/yr	1,806,200 AF/yr
220 GPCD (~0.25 AF/yr)	6,317,370 pop	6,823,390 pop	7,329,420 pop
200 GPCD (~0.22 AF/yr)	6,949,100 pop	7,505,730 pop	8,062,360 pop
175 GPCD (~0.20 AF/yr)	7,941,840 pop	8,577,980 pop	9,214,120 pop

* Municipal Supply equals Total Supply minus 189,000 AF/year reserved for industrial (“non-GPCD”) demand.

This projection indicates that the Sun Corridor has another decade or more left for sustainable population growth based on the particular definition of water supply used in this report. Obviously, any precise estimate is flawed by numerous assumptions which are likely to be wrong. Reality is a wide range of possible scenarios. It is important, therefore, not to view any of these projections as some kind of “wall” that growth will hit in the future.

This conclusion does suggest a less robust range for continued population growth in the Sun Corridor than was the case in 2011. This change is the result of the revised assumptions for decreased supply from the Colorado River’s structural deficit and from the impact of climate change, coupled with evidence of a flattening curve in decreasing water demand in the AMAs. However, we should not underestimate potential for lowering per capita water consumption. Conservation and reuse have a dramatic impact on population capacity and are manageable to a degree that water supply is not. In a study published in 2020, researchers surveyed 20 U.S. cities and found that while population increased by an average of 21% during 2000-2015, total water use decreased by an average of 19% over the same period. In fact, as the study points out, the U.S. Bureau of Reclamation in its 2012 Colorado River Basin Water Supply and Demand Study over-estimated future municipal and industrial water demands in the Basin. Just three years later, in 2015, the Bureau in conjunction with the Basin states found that water consumption across the Basin had dropped by 16% from 2000-2015. High-efficiency plumbing fixtures, cutting outdoor water use, water pricing, using recycled water for power generation and corporate water stewardship all contributed to this decrease in demand.[42]

Despite increased concern about the impacts of climate change, and despite the widely publicized Drought Contingency Plan, from a high-level perspective there is still room for continued growth in the Sun Corridor. But this new chart, like the one in 2011, makes a huge assumption: that large-scale commercial agriculture will go away. No water in either chart is reserved for agricultural use. This means continuing evolution away from all farming in the Sun Corridor—both Indian and non-Indian—that is based on renewable supplies. The chart also assumes that there will be no net increase in industrial, or non-GPCD, demand. These numbers also limit groundwater use in the Sun Corridor to only the “natural recharge” number. While we currently far exceed that amount, continuing to dewater ancient aquifers is unsustainable and contrary to the goals of the Groundwater Management Act.

The Next Bucket

While a detailed discussion of augmentation and demand management strategies to meet the Sun Corridor's future water demand is beyond the scope of this report, it is worth acknowledging that there are serious discussions and planning efforts underway to ensure water supplies for the region's future needs—and these strategies may facilitate population growth well beyond the limits stated in Chart 12.

In its 2019 report, the Long-Term Water Augmentation Committee of the Governor's Water Augmentation, Innovation, and Conservation Council identified augmentation options for the Sun Corridor, including:

- ocean water desalination,
- brackish groundwater desalination,
- importation of groundwater from designated basins, and
- increased reservoir and aquifer storage.[43]

The report also identified strategies for stretching existing supplies, including:

- more use of re-claimed water,
- urban enhanced run-off, and
- increased municipal and agricultural conservation.[44]

An additional augmentation possibility for the Sun Corridor is the importation of Colorado River supplies allocated to the Colorado River Indian Tribes. In 2019, the tribe voted to authorize the leasing of some supplies.[45]

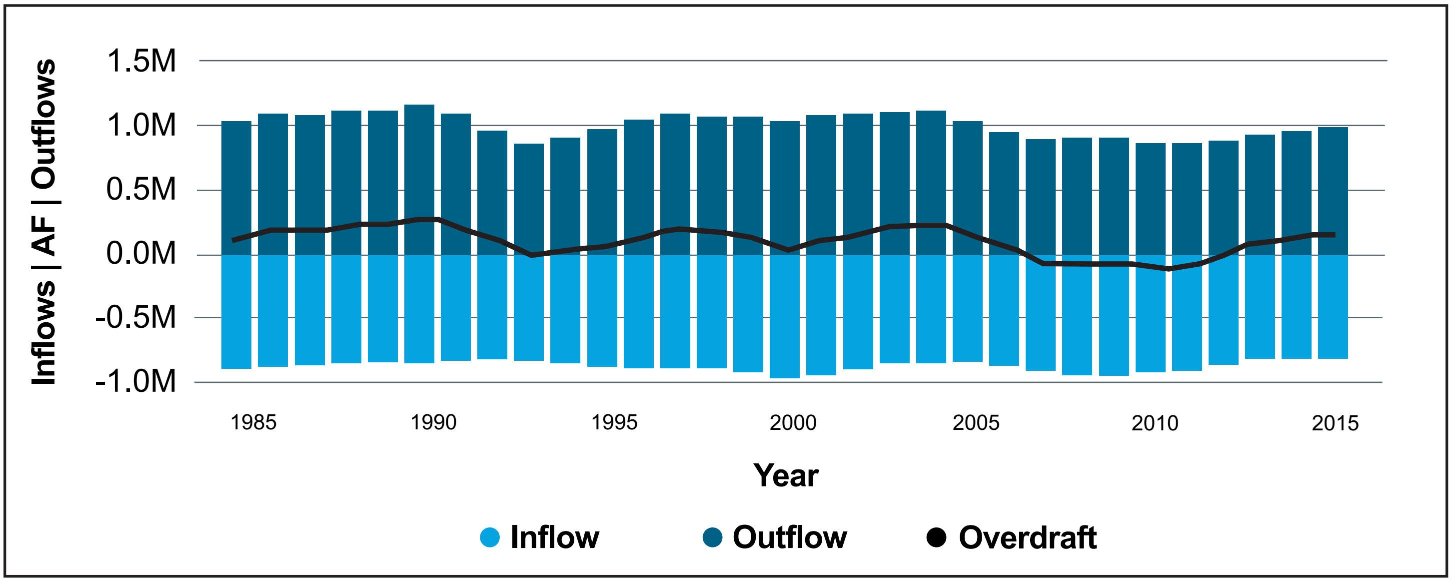
These and other augmentation concepts are detailed in the Kyl Center's Arizona Water Blueprint "Water Augmentation Concepts" story map.[46]

Sun Corridor Water Constraints

While this report intentionally ignores the complex legal, jurisdictional and physical challenges that stand in the way of moving water to and around the Sun Corridor to meet urban growth, it is important to keep them in mind:

- Arizona's in-state surface water is over-allocated and subject to a decades-long court process to establish the priority and extent of rights to use this water. This process stands in the way of the transfer of these rights to new uses. Meanwhile, groundwater pumping near some rivers may be reducing their flows.
- Most of the water of the Salt and Verde rivers is "appurtenant" to lands in Maricopa County served by older Salt River Valley cities. That is, the water must be used on those lands and may not be transferred for use elsewhere.
- Colorado River water delivered through the Central Arizona Project (CAP) is subject to permanent agreements between various municipalities, water companies and tribes and cannot be freely moved to other users or areas.
- Efforts to acquire rights from on-river users of Colorado River water so that the water may be used in Central Arizona face numerous hurdles, with river communities objecting to such transfers.
- The Central Arizona Groundwater Replenishment District (CAGRD), which is a responsibility of the District that operates the CAP, has facilitated urban growth on lands without a history of water use instead of on farmlands, resulting in new demands on the water supply rather than replacing existing demands. See note 17.

Chart 13: Phoenix AMA[47]

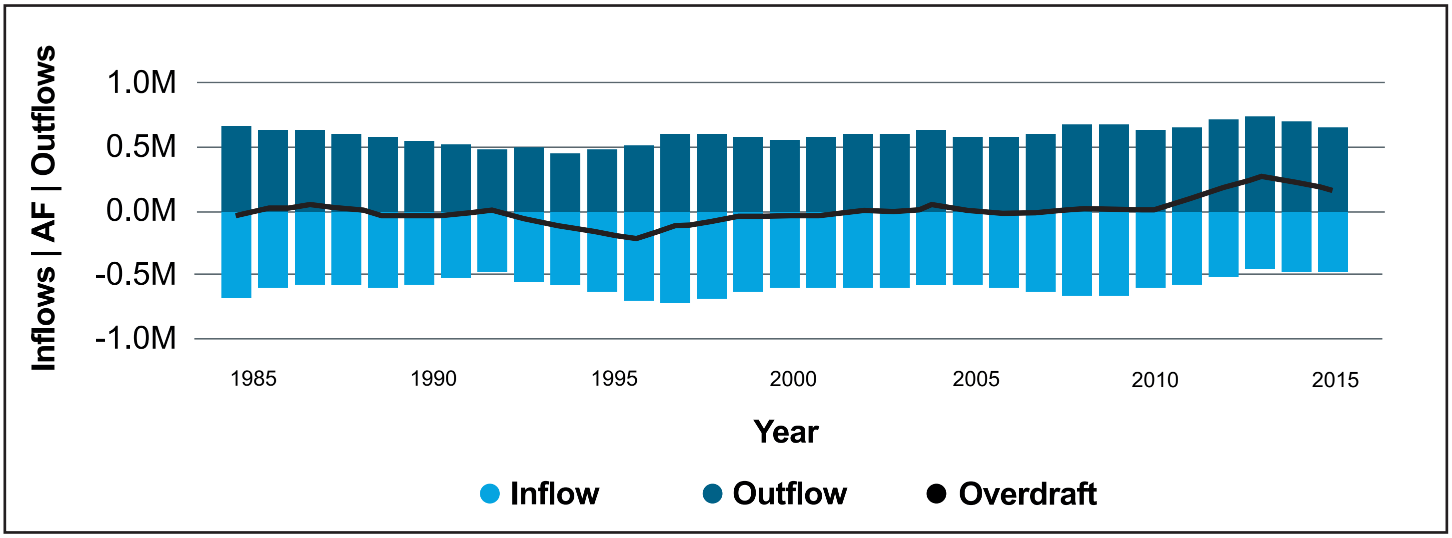


What Happens to Farming?

The immediate water issue in the Sun Corridor is not about subdivisions or landscaping or industry or population growth. It is about farming. The Phoenix Active Management Area is not currently achieving safe yield, primarily because of groundwater pumping for grandfathered groundwater rights, about half of which is for agriculture. As farming continues to be replaced by subdivisions, some knowledgeable observers feel that safe yield will be attainable, though continued urbanization of raw desert undermines this trend. For now, ADWR shows the Phoenix area overdraft averaging over 100,000 AF/year.[48]

Pinal's overdraft pattern is similar (see Chart 14):

Chart 14: Pinal AMA[49]



Once upon a time, we could shrug off concerns about the future of Pinal. Urbanization seemed imminent. Houses would displace farming in a relatively orderly timing. Abundant CAP water would be available until at least 2030 to sustain non-Indian agriculture as subdivisions were built. Then total water use would decrease, municipal systems would take over, and things would evolve much as they have in Maricopa County.

The two trend lines did not converge as anticipated. CAP water is being cut back earlier than expected and urbanization is happening more slowly. The result is a desire to preserve agricultural uses for a longer time, just as the water to do so is becoming scarcer; hence, the "cataclysmic" gap forcing farmers back onto groundwater and necessitating their request for financial assistance to retrofit pumps and subsidize operations.

For non-Indian farmers in Pinal County, the water crisis is tangible and immediate. Starting in about 2016, it began to become clear that the problem there extended beyond farming to a series of assumptions made about the availability of groundwater for growth. ADWR concluded that its groundwater models for the Pinal AMA were flawed and have a large "hole" of anticipated demand from potential subdivisions—a hole of 8 MAF over the 100-year horizon of which about 2 MAF is associated with assured water supply determinations previously issued by ADWR. This realization has paralyzed some types of development approvals.[50] There are conversations underway about ADWR's modeling and what ways might exist to close the gap.

The situation in Pinal is a harbinger of the complexity of transitioning from farming to urban uses in a time of declining and uncertain supply. The biggest lesson is that the simple assumption that Pinal farming would give way to urban growth is not a safe harbor when much of that farming is on groundwater. For areas of rural Arizona outside of the Sun Corridor, where urbanization is not the likely future, the decline of agriculture and the thirst of Central Arizona's urban areas represent even more serious threats. There are potential solutions to these problems, but the solutions are not simple.

To deal with agriculture/urban relationship in Pinal, some potential legislation should be considered:

1. It is time to rethink incentives to urbanize farmland in preference to raw desert. The Groundwater Management Act had mechanisms to begin this sort of preference, but the creation of the CAGRD altered those incentives. Because subdivisions use less water than farming, it makes sense to use public policy to incentivize growth on farmland as a means of achieving safe yield.[51]

2. The largest block of water in Pinal County belongs to the Gila River Indian Community (GRIC). The GRIC intends to use much of that for farming but it could move to urban uses if a financial assurance mechanism to protect 100 years' worth of payments can be created.[52] The analysis in this paper assumes this will be available for growth, **which is not necessarily a safe assumption**.

3. Farmland that is fallowed should be able to retain its preferential agricultural classification for property taxes until it is actually developed—otherwise there is a continuing incentive to use the water for farming even when an alternative makes sense.

The original report suggested reasons why there might be a benefit to sustaining agriculture in the Sun Corridor over the long term. Most significantly, farming annual crops, like grains or cotton, can provide water management flexibility allowing such use to shift to urban needs in times of shortage while providing growers the benefit of a dependable revenue stream. *Watering the*

Sun Corridor suggested that a 500,000 acre-foot reserve could be set aside for continued farming, most likely on Indian lands. Doing so would lower the potential population numbers by more than 2 million. Today it is probably too late to even consider such a proposal. For now, at least, it seems as though the dilemma of Colorado River availability and its impact on continued farming has preempted any potential consideration about preserving agriculture in Central Arizona.

Any long-term future for farming in the Sun Corridor lies largely with the Gila River Indian Community. The Community has a total allocation of more than 650,000 AF/year from a variety of surface water and groundwater sources, including the largest allocation of CAP water to a single user, at 311,800 AF/year. The Community is now in the process of building out an irrigation system which will dedicate significant water to as much as 146,000 acres of agriculture. However, in 2019, GRIC used only about 30,000 acre-feet for on-reservation agriculture. Another 75,000 acre-feet was leased to Sun Corridor cities under various arrangements. As is the case with non-Indian farmers, the viability of future agriculture for GRIC farmers depends on complex factors, including the cost of Colorado River water delivered via the CAP.

The Community is entitled to sell unused water allocated to it, and some have looked to unused GRIC CAP water as a long-term water source for non-Indian agriculture in Pinal County, though it is doubtful that farmers could afford such unsubsidized supplies. In conjunction with the Arizona DCP agreement, the GRIC agreed to lease a substantial quantity of water to the Central Arizona Groundwater Replenishment District.[53] These kinds of arrangements may well continue for decades. But imagine that the GRIC ultimately dedicate substantially all of their water to on-reservation farming. That would reduce the theoretical “carrying capacity” of the Sun Corridor’s water supply by nearly 3 million people—revising the calculations above to suggest that there is little room left for sustainable growth beyond our existing population.

The dialogue about the future of agriculture is now, inevitably, moving outside the Sun Corridor and to the west. Proposals to wheel new water supplies through the CAP canal have begun to be proposed. These could be groundwater from western basins like Harquahala or Butler Valley, or mainstream Colorado River supplies that have been used for farming along the river. **Full disclosure:** I represent a land owning entity along the Colorado River which is seeking to transfer water to the Town of Queen Creek, in one of the first transactions of this kind.

Water, it is often said, flows toward money. That isn’t quite right. Water flows toward people. The history of the West is a history of moving water to where people are and where it can be put to productive use. This history has built Arizona and made the Sun Corridor possible. This history has also had negative consequences to natural environments and sometimes to rural economies.

The Sun Corridor represents 82% of Arizona’s population and more than 90% of its economy. It has grown based on moving water from the mountains of Central Arizona through the SRP system and moving water from the Rockies through the CAP canal. To continue sustaining the Sun Corridor will ultimately require moving additional water. The most renewable—sustainable—source of such added supply is from the Colorado. Arizona’s entitlement from the river is 2.8 MAF. More than 1.3 MAF is currently used on the river; more than 90% of that is used for agriculture. Some of this water could be “wheeled” through the CAP canal into the Sun Corridor. The water is not—and would not become—CAP water. Rather the canal would be used as a transport mechanism for “mainstem” water shifted from farming along the Colorado to supporting urban growth in Central Arizona.

There is a stark difference between the Maricopa and Pinal ag/urban conversion and the potential conversion of on-river farming to urban uses. First, the agricultural uses in Central Arizona have historically been relatively low value, often fiber crops or alfalfa. These never supported the large and complex ag/industrial complex that exists around Yuma. That economy, based on vegetables, lettuce, melons and food crops, supports huge, cooled warehouses, massive shipping locations, and thousands of jobs. The on-river farming economy has to be of sufficient scale to support this complex integrated system.

Second, Pinal and Maricopa County farming has been slowly replaced over time by urban use in the same location. An in-place farm economy has been supplanted by an urban economy. Farmers have been rewarded by selling their land for subdivisions. La Paz and Mohave counties are not likely to follow this trajectory. Even Yuma's urban growth has remained relatively slow compared to Central Arizona.

Several recent proposals to transfer modest amounts of on-river ag water to urban uses off the river have drawn fierce opposition from citizens living in the on-river counties. ADWR and USBR have a process for considering such transfers but there are proposals to short circuit that consideration of statewide equities in favor of giving on-river counties a complete veto. Such proposals pitting one part of Arizona against another could have long-term negative consequences for the future of the Sun Corridor and the whole state. But it is time for a serious look at the importance of agriculture in Western Arizona—how to preserve it for the long term and how to mitigate any negative impact of transfers. There is a good case to be made that sufficient water could be acquired and moved from Western Arizona to supplement the Sun Corridor in the future without unduly hurting the on-river economy.[54]

It is Still All About Choices

Things have changed since 2011. The impacts of climate change are more apparent, lessening the reliability of the Sun Corridor's surface water supplies. At the same time, the long-term decline in per capita water use by urban populations may be leveling off. These trends suggest a less optimistic outlook.

The fundamental reality of water in the Sun Corridor remains the same: There is more water here than people realize. We have done a very good job over a very long time of building a complex and robust system for watering the Sun Corridor. The system has both flexibility and capacity to accommodate continued population and economic growth.

Every part of the world faces challenges from climate change. Urban areas on seacoasts will need to deal with sea level rise. Extreme weather events like hurricanes and tornadoes will increase. The arid parts of the world will get hotter and drier. The history of Arizona has been punctuated with climatic challenges. Our society is better positioned to deal with those challenges than was the case in the time of the Anasazi or the Hohokam. But we cannot escape reality—managing through increasing climatic uncertainty will be challenging.

For at least a decade I have ended talks on water with an analogy. People ask me, "Do we have enough water? When will we run out?" The answer, I tell them, is to ask: "Do you have enough money? When will you run out?" The questions, I try to explain, are parallel. The answers to both are always, "It depends."

The answers depend on what assumptions you want to make, how risk averse you are, and what goals you have. Do you want to put money into savings for the future? Do you want to dip into your inheritance? What do you want to hold in reserve in case things do not go as expected? How much do you want to leave for future generations? Are you willing to compromise your current lifestyle to protect future options?

The water supply numbers in *Watering the Sun Corridor* were an attempt to identify the anticipated “cash flow” of average annual water to support urban growth. Those numbers withdraw from prehistoric groundwater (think of it as the inheritance) only a “safe yield” (interest) that can be added to annual income. To protect against risk, we maintain two kinds of savings: water in reservoirs (like a passbook account) and groundwater banking (more like a certificate of deposit).

The difference in the analogy is who makes the decision. Your family does not get to manage your water supply. Water collection, storage, distribution and delivery necessarily involves collective action. The more arid the region, the larger the collective unit needed to manage water. That collective action is the history of the western U.S.

Things happen: Jobs are sometimes lost; income drops; the stock market falls; health problems appear. Snowpack declines; temperatures rise; growth patterns change. In the nearly 10 years since *Watering the Sun Corridor*, all sorts of things have happened. Urban Arizona remains equipped to deal with the challenges of managing a lot of people living in an arid environment. The lesson of those 10 years is the same now as it was then. Sustainability is all about choices. The difference is that those choices are coming much faster than we expected.

Notes

[1] Letter of Dir. Thomas Buschatzke to Hon. David Bernhardt (September 4, 2020) 8 https://new.azwater.gov/sites/default/files/20200904_ADWR_GSC_QC_Transfer_Recommendation.pdf (last visited October 18, 2020); Letter of Dir. Thomas Buschatzke to Leslie Meyers (January 20, 2021) (on file with the Kyl Center for Water Policy).

[2] Morrison Inst. for Pub. Policy, Ariz. State Univ., Watering the Sun Corridor 36 (Grady Gammage Jr. et al. eds., 2011), https://morrisoninstitute.asu.edu/sites/default/files/sustphx_watersuncorr.pdf.

[3] *See generally id*. at 26–32.

[4] Andrew Ross, Bird on Fire 15 (Oxford Univ. Press, 1st ed. 2011).

[5] William "Bill" DuBuys, A Great Aridness 309-12 (Oxford Univ. Press, reprt. ed. 2013).

[6] *See generally* Paolo Bacigalupi, The Water Knife (Vintage, reprt. ed. 2016).

[7] Abrahm Lustgarten, *How the West Overcounts Its Water Supplies*, New York Times (July 17, 2015), https://www.nytimes.com/2015/07/19/opinion/sunday/how-the-west-overcounts-its-water-supplies.html.

[8] Joanna Walters, *Plight of Phoenix*, The Guardian (March 20, 2018), https://www.theguardian.com/cities/2018/mar/20/phoenix-least-sustainable-city-survive-water.

[9] Eric Holthaus, *Yes, the Drought is Bad in California. It's Going to Be Much, Much Worse in Arizona*., Slate (May 8, 2015), https://slate.com/technology/2015/05/arizona-water-shortages-loom-the-state-prepares-for-rationing-as-lake-mead-hits-record-low.html?via=recirc_recent.

[10] William Yardley, *Shrinking Colorado River is a growing concern for Yuma farmers & millions of water users*, Los Angeles Times (July 18, 2015), https://www.latimes.com/nation/la-na-sej-colorado-river-arizona-20150719-story.html.

[11] Holthaus, *supra* note 9.

[12] Ian James, *At water-starved Lake Mead and Lake Powell, 'the crisis is already real,' scientists say*, azcentral (August 28, 2018) https://www.azcentral.com/story/news/local/arizona-environment/2018/08/28/scientists-colorado-river-water-crisis-lake-powell-mead/1088871002/.

[13] Mike Pearl, *Phoenix Will Be Almost Unlivable by 2050 Thanks to Climate Change*, Vice (September 18, 2017) https://www.vice.com/en_us/article/vb7mqa/phoenix-will-be-almost-unlivable-by-2050-thanks-to-climate-change.

[14] Dashks Slater, *Can Phoenix Remain Habitable?*, Sierra (January 2, 2019), https://www.sierraclub.org/sierra/2019-1-january-february/feature/can-phoenix-remain-habitable.

[15] A number of other Arizona entities have the same junior priority as the CAP—as does Nevada.

[16] *Arizona v. California*, 373 U.S. 546 (1963).

[17] Establishment of the Central Arizona Groundwater Replenishment District has facilitated subdivision development on raw desert, which results in net increases in regional water demand, rather than on converted agricultural lands, which typically results in net decreases in regional demand. The CAGRD is discussed in depth in the Kyl Center's 2019 report The Elusive Concept of an Assured Water: the Role of CAGRD and Replenishment. Since 2005 more than half of new homes developed in the CAP service territory are enrolled in the CAGRD. Central Ariz. Groundwater Replenishment Dist., *2019 Mid-Plan Review* 11, https://www.cap-az.com/documents/departments/cagrd/2019-CAGRD-Final-Mid-Plan-Review-022420.pdf.

[18] Ariz. Dept. of Water Resources, Long Term Storage Account (LTSA) Summary (November 30, 2020), https://new.azwater.gov/sites/default/files/media/2019%20LTSA%20Summary%2011-30-2020_1.pdf. Last visited February 4, 2021).

[19] Ted Cooke, "Lake Mead Structural Deficit Adds to Issues of Drought and Shortage," CAP Blog (December 2, 2015) https://www.cap-az.com/public/blog/466-lake-mead-structural-deficit-adds-to-issues (last visited March 10, 2020).

[20] Cong. Research Servs., Management of the Colorado River 15 (2019).

[21] In addition to agreed cuts, the DCP contains provisions that incentivize water users to "conserve" water in Lake Mead, thereby keeping lake levels up.

[22] Natural Resources Defense Council, Climate Change, Water, and Risk: Current Water Demands Are Not Sustainable (July 2010), https://www.nrdc.org/sites/default/files/WaterRisk.pdf.

[23] SRP has made the Kyl Center aware of U.S. Geological Survey data showing that the average flow into SRP's reservoir system is higher, at 1,152,380 AF/year (based on historic gauge data from 1913-2019 for Verde River below Tangle Creek, Salt River near Roosevelt Reservoir and Tonto Creek above Gun Creek). However, some of this water is allowed to flow into the Salt River bed where it filtrates into the aquifer and may be counted as natural groundwater recharge.

[24] This analysis focuses on the three Active Management Areas (AMAs) overlapping the CAP service territory, Phoenix, Pinal and Tucson AMAs. Designated by the state's groundwater code, each of the state's five AMAs is subject to groundwater regulations aimed at achieving a specified management goal. The goal for the Phoenix and Tucson AMAs is "Safe Yield;" that is, a long-term balance between the amount of groundwater withdrawn and the annual amount of natural and artificial recharge in the AMA. The Pinal AMA goal is to allow development of non-irrigation uses and to preserve existing agricultural economies in the AMA for as long as feasible, consistent with the necessity to preserve future water supplies for non-irrigation uses. Ariz. Dept. of Water Resources, Active Management Areas (AMAs), https://new.azwater.gov/ama, (last visted February 4, 2021).

[25] Cent. Ariz. Project, Shortage Impacts to CAP Priority Pools and Customers (April 22, 2015), https://www.cap-az.com/documents/shortage/Water-Planning-Ops.pdf.

[26] Ian James, *Rising temperatures are taking a worsening toll on the Colorado River*, AZCENTRAL (February 22, 2020) https://www.azcentral.com/story/news/local/arizona-environment/2020/02/22/global-warming-rising-temperatures-worsening-toll-colorado-river-climate-change/4832434002/.

[27] Recent research suggests climate change will have less dramatic impacts on the SRP System's water supply because snowpack and reservoir-filling snow-melt occur earlier in the year than in the Colorado, resulting in lower evaporative losses. Kevin W. Murphy & Andrew W. Ellis, *An analysis of past and present megadrought impacts on a modern water resource system*, HYDROLOGICAL SCIENCES J. (2019) https://doi.org/10.1080/02626667.2019.1571274.

[28] Recent coverage by The Arizona Republic, Arizona Daily Star, and KJZZ on water issues is greatly improved and evidences much more sophisticated understandings of these issues.

[29] Enlarging Bartlett Lake Reservoir is one of the alternatives under consideration in the Verde River Sediment Mitigation Study, an undertaking of SRP and U.S. Bureau of Reclamation. *See* SRP, *Sediment issue at Horseshoe Dam and Reservoir*, WWW.SRPNET.COM, https://www.srpnet.com/water/dams/horseshoe-sediment.aspx (last visited October 25, 2020).

[30] However, ADWR reports that "most of the ideal locations for large-scale recharge facilities have already been permitted in the [Phoenix AMA]." ARIZ. DEPT. OF WATER RESOURCES, FOURTH MANAGEMENT PLAN PHOENIX ACTIVE MANAGEMENT AREA 2010-2020 11-5, https://new.azwater.gov/sites/default/files/media/FULL%20FINAL%20PHX%204MP_1.pdf.

[31] ARIZ. DEPT. OF WATER RESOURCES, AMA Data, https://new.azwater.gov/ama/ama-data (last visited October 18, 2020).

[32] As stated in Note 23, the Sun Corridor statistics used in this report are restricted to the Phoenix, Pinal, and Tucson Active Management Areas.

[33] *See generally*, KATHLEEN FERRIS AND SARAH PORTER., THE ELUSIVE CONCERPT OF AN ASURED WATER SUPPLY (2019) https://morrisoninstitute.asu.edu/sites/default/files/kyl_center_elusive_concept_101619.docx.pdf.

[34] ARIZ. COM. AUTH., "Population Estimates," https://www.azcommerce.com/oeo/population/population-projections/ (last visited October 12, 2020).

[35] ADWR defines "total GPCD" as "the total gallons of water per capita per day for all non-irrigation uses (i.e., non-farming uses) supplied by a municipal provider." ARIZ. DEP'T OF WATER RESORCES, MANAGEMENT PLAN SECOND MANAGEMENT PERIOD: 1990–2000, PHOENIX ACTIVE MANAGEMENT AREA 140 (1991), http://infoshare.azwater.gov/docushare/dsweb/Get/Document-10661/PHXAMA%202MP%20Complete.pdf. In calculating total GPCD, ADWR includes lost and unaccounted-for water.

[36] ARIZ. DEPT. OF WATER RESOURCES, AMA Data, https://new.azwater.gov/ama/ama-data (last visited October 18, 2020) (based on "Large Provider" population and deliveries).

[37] City of Phoenix, City of Glendale and Town of Gilbert, Phoenix Metropolitan Area Multi-City Water Use Study: Single-Family Residential Sector 20 (2019). https://www.documentcloud.org/documents/6681931-2019-Executive-Report-Phoenix-Metro-Household.html.

[38] Ariz. Dept. of Water Resources, AMA Data, https://new.azwater.gov/ama/ama-data (last visited October 26, 2020) (includes Municipal and Industrial demand categories except drainage and dewatering demand, reclaimed water used for Palo Verde Nuclear Generating Station and water used for mining in the Tucson AMA).

[39] *Id*.

[40] Morrison Inst. for Pub. Policy, *supra* note 2, at 27.

[41] Ariz. Dept. of Water Resources, AMA Data, https://new.azwater.gov/ama/ama-data (last visited October 26, 2020) (based on Industrial demand, drainage and dewatering omitted; 70,000 AF/year effluent demand omitted for Palo Verde Nuclear Generating Station). Industrial demand includes sand and gravel operations, golf courses, parks, schools, cemeteries, large HOA common spaces, large cooling towers, power generation facilities, dairy facilities, feedlots and mines. In the Phoenix AMA, industrial demand has trended upward over the last decade or so.

[42] Brian D. Richter et al., *Decoupling Urban Water Use and Growth in Response to Water Scarcity*, 12 Water 2868 (2020), https://doi.org/10.3390/w12102868.

[43] Carollo Engineers, Long Term Water Augmentation Options for Arizona 8 (Aug. 2019), https://new.azwater.gov/sites/default/files/Long-Term%20Water%20Augmentation%20Options%20final.pdf.

[44] This report builds on the Arizona Department of Water Resource's 2014 report, Arizona's Next Century: A Strategic Vision for Water Supply Sustainability, https://new.azwater.gov/sites/default/files/media/ArizonaStrategicVisionforWaterResourcesSustainability_May2014%20%2817%29.pdf.

[45] John Gutekunst, *CRIT voters approve ordinance to allow for leasing some water rights*, Parker Pioneer (January 20, 2019, updated November 14, 2020) https://www.parkerpioneer.net/news/article_74873a86-1d22-11e9-8eba-c39eacdf5e0f.html.

[46] Natalie Kilker, Augmentation Concepts—Arizona Water Blueprint, https://azwaterblueprint.asu.edu/feature/water-augmentation-concepts (last visited February 4, 2021).

[47] Ariz. Dept. of Water Resources, AMA Data, https://new.azwater.gov/ama/ama-data (last visited October 18, 2020).

[46] *Id*. (AMA Overdraft Dashboard, "Long-Term Analysis: Proposed Method"; 20 year running average Natural Components, 3 year running average artificial components).

[49] *Id*.

[50] Ian James, *In Pinal, groundwater insufficient to meet long-term projected demands, officials say*, AZCENTRAL (Oct. 19, 2019) https://www.azcentral.com/story/news/local/arizona-environment/2019/10/12/long-term-projections-show-insufficient-groundwater-pinal-county/3948754002/.

[51] Kyl Ctr. for Water Policy at Morrison Inst., *supra* note 33, 27.

[52] For example, Community Facility Districts in new subdivisions could be authorized to add water acquisition costs into the infrastructure expenditures covered by assessments.

[53] Kyl Ctr. for Water Policy at Morrison Inst., *supra* note 33, 14-15.

[54] As an example of such water sharing agreements, we can look to the 35-year deal between Metropolitan Water District of Southern California ("Met") and California's Palo Verde Irrigation District in which Met pays farmers to fallow their fields to make water available for Met's municipal water provider customers. *See* Metropolitan Water District of Southern California, *Palo Verde Land Management, Water Supply and Crop Rotation . . . at a glance* (June 2013) http://www.mwdh2o.com/MWD_PDF/NewsRoom/6.4.2_Water_Reliability_Palo_Verde.pdf#search=palo%20verde%20irrigation%20district. It should be noted that the Yuma agricultural region differs from Palo Verde Irrigation District in significant ways, including in the types of crops produced. What works for the Met and PVID would not necessarily work for Yuma farmers.

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