

RETHINKING WATER IN THE ARID SOUTHWEST: THE NEED FOR A NEW FRAMEWORK FOR MANAGING WATER IN ARIZONA

Anderson¹, G., Dick¹, E., Minor^{1,2}, J., and Prichard¹, A.

Abstract

Arizona's Five Cs (copper, cattle, citrus, cotton, and climate) represent a suite of economic practices, which have very material effects on Arizona's water resources. These Five Cs have long dominated the development of Arizona's water policy and law while disregarding the natural limitations of the state's hydrologic resources. Perhaps more than any other western state, Arizona has undergone rapid and striking demographic changes across the course of the 20th and 21st centuries. This paper:

- Provides a grounding in the paleoecological and historical records of past drought in the Southwest, as well as in predictions for the climate change that Arizona will experience in the future.
- Explores changes in Arizona water law over time, especially with regards to shifts in the types of water which are actively managed, and the institutions charged with managing Arizona's overallocated water resources.
- Documents how the changing economic needs of powerful Five C actors has driven changes in water law over Arizona history.
- Addresses the role of science in creating policy to plan for drought and climate change.

Finally, this paper provides a realistic look at Arizona's priorities and policies regarding water, with an emphasis on a new set of Five Cs which place heightened importance on sustainable agriculture and water-conscious urban planning.

Introduction

For generations, Arizona's schoolchildren were taught about the Five Cs: copper, cattle, cotton, citrus, and climate. These entities were identified as the driving forces behind the state's economy and of paramount importance in the development of Arizona's identity. Activities associated with the Five Cs have had a lasting impact on the physical landscape and hydrology within the state. Additionally, they have played an important role in shaping water policy and law in Arizona. With our improved understanding of the arid nature of the region, it has become clear that water policy developed around the Five Cs is no longer sustainable in the context of booming populations and predicted future climate scenarios. We seek to reimagine the concept of the Five Cs as a means toward understanding drought and water policy in Arizona.

Each of the Five Cs, in addition to representing an entrenched political force in the state, is something through which water flows. Water percolates through mine tailings, sprinkles over golf course fairways, and cycles through cattle troughs, cotton fields, and citrus groves. The Five Cs, as political actors enmeshed within a network of relationships centering on water and drought, give power and priority to certain agents and activities while marginalizing others, including Native American communities and the environment. The use and management of water for the benefit of these activities has forever altered the relationship between people and the land in Arizona, and to continue enacting these relationships into an uncertain future no longer makes economic or ecological sense.

¹ School of Geography and Development, University of Arizona, Tucson, AZ

² Address correspondence to Jesse Minor, University of Arizona, School of Geography and Development, PO Box 210076, Tucson, AZ 85721, USA. Email: jminor@email.arizona.edu

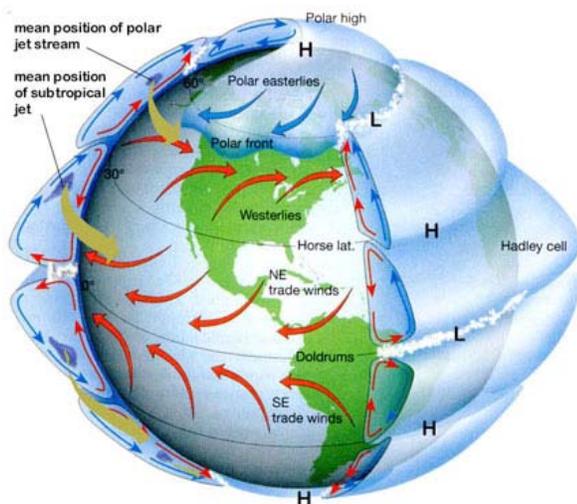
The obsolescence of Arizona’s Five Cs has been recognized for some time now, with Congressman Morris Udall worrying in 1984 “about water and its ability to sustain cotton, cattle and citrus.” He even expressed concern over climate “to the extent that melting snows along the upper Colorado River last spring and torrential summer rains caused flooding in places like Tucson, Yuma, Nogales and Marana. One thing is clear: the Five Cs can’t be taken for granted anymore” (Udall 1984). There is also an increasing awareness that the water of the desert southwest is not constrained by geopolitical boundaries, as many watersheds in southern Arizona flow to or from Sonora, Mexico. It is time for water policy and law to catch up with these recognitions.

We slightly refine the historical Five Cs for the purposes of this paper. Cotton and citrus are combined into the broader category of crops, and climate is understood not in a literal sense, but in the sense that the booming residential development experienced in Arizona since the 1950s has been as much about selling sunshine as selling houses. Using this consolidated understanding of the Five Cs, we explore the history of drought and water policy in Arizona. We conclude with a set of recommendations for a new set of Five Cs that could shift Arizona to a more sustainable path in the future.

This paper focuses largely on Arizona, but hydrologic and climatologic processes do not recognize political boundaries. As such, our discussion of the climatic features of drought includes most of the southwestern United States and northwestern Mexico. The focus on Arizona necessarily includes a discussion of international and interstate water agreements, as well as shared river basins that impact the state.

1. The nature of climate in the region (seasonal characteristics, sources of moisture, mechanisms that control climate and drought) of the southwestern United States and Northern Mexico

The marketing of Arizona as a prime place for agriculture’s thirsty crops and unlimited water for human use neglects the climatic context of the region. The southwestern United States and northwestern Mexico are characterized by a hot, arid climate at low elevations with high desert and forested regions at higher elevations. Arizona’s average temperature is 17°C (62°F); its sister state to the south, Sonora, Mexico, has an average temperature of 25°C (77°F). The highest recorded temperature for Arizona, 53°C (128°F), occurred July 29, 1994 (Sheppard *et al.* 2002). Southern Arizona’s average annual rainfall is a mere 13.09 inches (USGS 2005).



Latitude and proximity to the Pacific Ocean, the Sea of Cortez, and the Gulf of Mexico, give the region a climate with distinct seasonal patterns. Since much of this area lies in a high-pressure band between 30° and 35° North latitude, nicknamed the “Horse latitudes,” it straddles the border between the Hadley and Ferrel cells during spring and fall, thus missing the winds and precipitation conveyed by the Prevailing Westerlies to the north and the Northeast Trade Winds to the south. During the winter and spring, however, the high pressure band moves north or south, bringing in relief of rain either from the Gulf of Mexico (in a summer monsoon season) or from the Pacific (in the winter rainy season).

Figure 1. GLOBAL WIND PATTERNS³

³ <http://www.sbg.ac.at/ipk/avstudio/pierofun/atmo/el-scans/hadley.jpg> 12 November 2009

Approximately 40-70% of the precipitation in the southwestern United States and northwestern Mexico occurs during the summer monsoon season, in which the Northeast Trade winds, fueled by the Bermuda High, bring warm, moist air from the Gulf of Mexico across Mexico and into the southwestern United States, pushing the high pressure zone well north of 30° until September, when the air mass cools down and moves southward again. A second precipitation event, bringing an average of 30% of the southwest's annual precipitation, comes in the winter in a phenomenon called troughing, in which the cold polar air mass expands southward, shifting the Ferrel Cell southward enough to encompass the American Southwest and northwestern Mexico. During this time, the Prevailing Westerlies, which are generally responsible for the high-precipitation climate of the Pacific Northwest, bring rain to the Southwest (Sheppard *et al.* 2002).

In addition to precipitation, the region depends heavily on groundwater, local rivers, and water derived from snowmelt in the Upper Colorado River Basin. (Figure 2) However, variations in snowfall, earlier snowmelt, diversions, and groundwater table decline has led to the drying of many rivers in the area. Urbanization and increasing water demand exacerbates this aridity.



Figure 2. Major rivers of Arizona.⁴

2. The characteristics of drought in the region and the history of major drought

Understanding the characteristics of drought in this region is complicated by the rapid shift in land use patterns that coincide with the settlement of the West. The driving force behind this early development in the West is directly linked to cattle ranching and copper mining, two of Arizona's

⁴ http://treeflow.info/loco/images/loco_map.png

historical Cs (Bahre 1991; Worster 1985). Due to the frequency of drought in this region, changes in land use and the resulting impacts on ecology and hydrology often coincide with drought, making it difficult to assign cause to either people or climate. It is clear, however, that the changing landscape of the American Southwest is a result of both human activity *and* climate (Seager *et al.* 2007; Hastings 2002). If climate change is understood as an anthropogenic occurrence, and viewed alongside land use change, the magnitude of human impacts on the southwestern United States and northwestern Mexico becomes apparent. However, uncertainty remains about how anthropogenic climate change will impact areas on a regional scale (Das *et al.* 2009). This level of uncertainty is especially problematic for Arizona, given its rapidly growing population and its heavy reliance on surface water sources (Pearce 2007).

Unfortunately, drought is not uncommon in the region. This area experiences regular multi-year droughts due to land surface- ocean teleconnections (Sheppard *et al.* 2002; Seager *et al.* 2009; Cook *et al.* 2007). Recent work by climatologists has linked the El Niño Southern Oscillation (ENSO) to drought over the southwestern U.S. and Northern Mexico. Specifically, La Niña-like sea surface temperatures (SSTs) in the Eastern Tropical Pacific have been identified as the key drivers of drought in the region (Sheppard *et al.* 2002). Additional factors such as warm subtropical North Atlantic SSTs appear to be linked, but the mechanism is not well understood. Also poorly understood are the causes of the changing tropical Pacific SSTs that drive drought (Seager *et al.* 2009, Cook *et al.* 2007). The most severe droughts in this region, such as those of 1729, 1748, and 1847, tend to last about three years, which is the average time between ENSO events (Sheppard *et al.* 2002). The 1950s drought, which peaked in 1956, lasted more than a decade. The current drought, spanning 1999-2009, has not yet reached the severity of the major droughts of the 20th century, namely the 1930s Dust Bowl drought and the 1950s drought. The Pacific Decadal Oscillation (PDO) has a period of several decades, and is a likely driver of Southwestern climate when the PDO is in its negative “cold” phase, such as the greatest southwestern drought in a millennium, that of the 1500s, which persisted for much of the century (Sheppard *et al.* 2002).

Drought is notoriously difficult to define. The most basic explanation is that drought occurs when there is simply not enough water to meet needs (CLIMAS 2007). Some natural disasters, such as floods or fires, have impacts that are immediately clear. It may take a year or two for a drought to be recognized, and as with the present drought affecting the Southwest, the concern is often as much about the future impacts if the drought continues as it is about the present situation (Harding 2005).

Despite drought’s ambiguities, it undeniably has multiple impacts. Drought affects ecosystems, and can reshape the ranges of plant and animal species, as well as increase the risk of wildfire (CLIMAS 2007). The economic impact of drought is estimated to have cost the United States roughly \$144 billion dollars between 1980 and 2003 (Cook *et al.* 2007). In northwestern Mexico, where infrastructure is less prepared to buffer against drought than in the United States, more than 2 million acres of farm land have been forced out of production since the present drought began in 1996. Additionally, drought is often cited as one of the causes for increased emigration from Mexico to the United States (Seager *et al.* 2009). The drought of the 1890s in the American Southwest, coupled with shifting land use practices, demonstrated that regional hydrology can be permanently altered (Bahre 1991; Hastings 2002).

The Palmer Drought Severity Index (PDSI) has been used to identify periods of drought in reconstructed paleoclimate and instrumental records (Sheppard *et al.* 2002; Cook *et al.* 2007). Using this index, several major multi-year droughts have been identified in the Southwest and northern Mexico over the last 200 years. Particularly important were droughts in the 1860s, 1890s, 1930s, 1950s, and the current drought that began in the mid to late 1990s (Cook *et al.* 2007; Seager *et al.* 2009, 2007; Sheppard *et al.* 2002).

The 1890s drought is credited with pushing the federal government to adopt a new policy approach to westward expansion that led to the enactment of the Reclamation Act of 1902. In responding to the pressures posed by the drought, the government was tacitly admitting some of the untruths surrounding the myth of an abundant West in which all that was needed to thrive was a plow and hard work (Seager and Herweiger 2007). There is some question, however, as to whether the 1902 Reclamation Act was a response to the drought, or rather to the increasing political pressure from a more populated West (C.J. Bauer, personal communication, 8 October 2009). The 1930s "Dustbowl Drought" is legendary in American History. This drought was most severe in the Midwestern United States, but also had a substantial impact on the southwestern states and northwestern Mexico. The 1950s drought is notable for its duration (Cook *et al.* 2007), lasting over a decade in a time when post-war expansion was fueling the urban population growth in much of the southwestern United States.

The present drought, which began in northern Mexico in 1994 and in the southwestern United States in 1999, continues to test the storage capacity on the Colorado River and tax regional aquifers. Though it is not yet considered as severe as major 20th century droughts, water managers are paying close attention. With reservoirs on the Colorado dipping to as low as 40% of capacity and over 30 million people and agricultural irrigators in Arizona and California relying on this water, the stakes have certainly never been higher (Harding 2005; NBII 2009).

The recent history of drought in the Southwest and northern Mexico parallels a history of development and settlement driven by manifest destiny and later by post-WWII population growth. This settlement displaced Native American populations as their lands were appropriated by settlers (Nevins 2008; Seager and Herweiger 2007). Early settlers were mainly engaged in cattle ranching and mining. Technological improvements in groundwater pumping, coupled with investment in major water storage projects by the Bureau of Reclamation, such as the Hoover Dam, and transfer infrastructure projects, such as the Central Arizona Project, paved the way for agriculture to take hold in the region. The advent of air conditioning helped make the climate in the Southwest more tolerable, which fueled post-WWII population booms in much of the Southwest (Worster 1985). These historical factors provide the basis of the Five Cs' impact on regional water management.

3. Evidence of past droughts recorded in the paleoclimatic data, and projections for future climate change and their impacts

Beyond the reach of the instrumental climate record, paleoclimatologists have documented numerous periods of extreme drought in the region, largely through the use of dendrochronology. Several particularly severe droughts have been documented. Of note are the Puebloan droughts from 1276-1297 and 1666-1671, which are credited with destabilizing Native American civilizations in the Southwest (Worster 1985). Archaeological evidence suggests that social causes may have contributed to this destabilization, but there is little doubt that drought was also a factor (Worster 1985). The evidence of historic drought of greater severity and duration than anything experienced in recent history increases the importance of understanding and preparing for major drought in this region.

Several types of proxy data provide a longer climate history than the instrumental record in the southwestern United States. In particular, packrat (*Neotoma* spp.) middens preserve evidence of broad scale vegetation changes in the southwest by encrypting seeds in rodent dens. This type of record has provided evidence that the southwest was previously a much wetter and cooler environment; prior to about 12,000 BP, areas which are now desert contained pinyon-juniper woodlands and chaparral grasslands (Swetnam *et al.* 1999).

The shift from the wetter Pleistocene to the dryer Holocene climate was perhaps quite sudden, and the geo-archeological record provides evidence of a long drought in the southwest around the time that the climate was shifting (11,000 BP). An investigation at a Clovis-period archeological site

revealed a mammoth kill on a Southern Arizona river bank for a river that never again flowed quite as high (Haynes 1991). Further evidence of permanently altered conditions was inferred from a layer of algal mats in the soil, suggesting formerly cienega-like conditions. Human- and animal-dug wells in the former floodplain also suggest that the water table dropped or was dropping during the Clovis period (*Ibid*). These rapid shifts in water tables and climatic conditions should serve as harbingers of potential future scenarios which might affect the American Southwest.

In addition to a more arid Holocene baseline climate, the Southwest has also experienced extended periods of drought, as evidenced by dendrochronological data. The Medieval Climate Anomaly from 900-1300 AD was considerably drier than any recent drought conditions (Cook *et al.* 2009). The so-called Puebloan droughts from 1275-1297 AD and 1666-1671 AD were also extensive and severe (Worster 1985). These droughts are indicated by narrower tree-ring widths and fire scars; evidence of fire scars over broad geographic scales is linked to drought conditions (Swetnam and Betancourt 1997). There is some correlation between tree ring-widths and El Niño and La Niña cycles, as well as evidence of cyclical insect outbreaks corresponding to wetter periods (Swetnam and Betancourt 1997)⁵. In Mexico, tree-ring data have successfully been used to verify models of SST forcings (Seager *et al.* 2009).

Evidence of past droughts makes it difficult to draw definitive conclusions about the causes of current drought because, as noted above, past droughts during the MCA exceeded current conditions, and data in the tree-ring record make it difficult to discern whether current conditions are within the range of natural variability or stem from anthropogenic climate forcing (Seager *et al.* 2009). However, there have been strong predictions of increasing drought in the southwest under human-mediated climate change:

- Warming in western North America is projected to cause decreased snowpack, more winter flooding, and reduced summer flows (IPCC AR4 2007).
- Heavily-utilized groundwater in the Southwest is likely to experience additional stress (*Ibid*).
- The American Southwest will become increasingly arid, and greenhouse gases could force medadroughts (Cook *et al.* 2009).
- By 2050, Colorado River reservoirs will not be able to meet the demands placed on them. Any reduction in precipitation will lead to a failure to meet allocations (Barnett *et al.* 2004).
- Increased average annual temperature, decrease in winter and summer precipitation (Bales and Liverman 1997).

There is some evidence that these changes are already underway. A study of 24 weather stations in the Sonoran Desert between 1960 and 2000 showed increasing minimum and maximum temperatures at all of the coastal instruments (Weiss and Overpeck 2005). Thus, the while the U.S. Southwest may be inherently drought-prone, future drought conditions will likely be intensified because the baseline is shifting towards a more arid climate (Seager *et al.* 2007).

4. The water rights system: major laws and regulations affecting the allocation and control of water resources

While the climate of the U.S. Southwest is often discussed in context of its aridity, the landscapes of the desert southwest are less shaped by the absence of water than by the abundance of it (*sensu* Childs 2000). A similar case could be made for the water policies of the desert southwest: they are less defined by the natural scarcity of water than by the assurance that certain users will have

⁵ It is important to note that the fire scar record is markedly less useful following fire suppression and timbering operations in the southwest (Swetnam and Betancourt 1997).

unfettered access to this resource. Overarching doctrines have been in place longer than the state has formally existed, and the laws and policy governing water use have been slow to change since then. It is clear, however, that water rights have been consistently manipulated in ways which have favored the rapid development of Arizona, including the interests who benefit from the growth and exploitation of Arizona's Five Cs.

Arizona water law defines four discrete types of water: surface water, groundwater, Colorado River water, and effluent. These waters are all subject to various levels of regulation, with a range of discrete rights and policies attached to the use and transfer of the water resource. These four varieties of water are also considered discrete entities, without continuity or interconnections in the hydrological cycle.

Surface Water

Surface water in Arizona, as in 19 states in the western United States, is governed by the doctrine of prior appropriation (Gillilan and Brown 1997; Getches 1994). In brief, prior appropriation is a rejection of the common-law riparian doctrine common in humid states, in which land owners can make use of water on or flowing across their property. Prior appropriation does not tie water rights to land adjacent to water, and firmly establishes the notion of 'first in time, first in right,' in which senior rights-holders gain precedent over later water users (Gillilan and Brown 1997).

The doctrine of prior appropriation was encoded by the Arizona territorial legislature in 1888, and was enshrined in the state constitution of 1912 (Pearce 2007). Water allocations quickly outstripped available supply, and by 1919 the situation was so critical that the Public Water Code was enacted to regularize water appropriations through a permit system (Pearce 2007).

Territorial legislation and adoption of the Arizona constitution did not settle the issue of Tribal water rights. The 1908 U.S. Supreme Court decision in *Winters v. United States* established the doctrine of federal reserved rights, which held that the federal government likely intended to "reserve" water rights for Indian reservations and other federal lands at the time of their creation. Therefore, tribes were ruled immune from water litigation until 1952 (Pearce 2007). Federal reserved water rights have influenced surface water law in several additional important ways. The *Gila River III* case (1999) made explicit connection between surface water and groundwater, particularly in that federal reserved rights to surface water can be protected from nearby groundwater pumping, and that federal reserved rights even extend to groundwater. The *Gila River V* court case (2001) extended the logic of federal reserved rights to a weighing of the original purpose of the appropriation against competing water interests, such as the creation of an Indian reservation against irrigated agricultural interests (Pearce 2007). Finally, water claims settlements led to 48% of the Colorado River water delivered through the Central Arizona Project (discussed below) belonging to Native Americans (August and Gammage 2007).

Groundwater

Before the advent of diesel pumps created the possibility of overdrafting groundwater supplies, Arizona groundwater was considered to be the property of the overlying landowner. A series of court cases sought to clarify whether groundwater was subject to prior appropriation. In *Maricopa County Municipal Water Conservation District No. 1 v. Southwest Cotton Company* (1931), the Arizona Supreme Court ruled that prior appropriation rights do not apply to groundwater, but two decades later the court reversed its opinion in *Bristor v. Cheatham* 1952 (Pearce 2007). The Court again reversed itself in *Bristor v. Cheatham II* (1953), when it adopted the American Rule, which allowed 'reasonable use' of groundwater on the property from which the water was extracted, but prohibited transfer of that water to adjacent properties. The American Rule itself was altered in *Jarvis v. State Land Department*

I, II and III (1969, 1970, 1976) when it became obvious that restrictions against groundwater transfer were hindering Arizona's rapid development (Pearce 2007).

These changes to the American Rule set the stage for very rapid urban development in Arizona. Unfettered development, coupled with rapid and unsustainable groundwater pumping, led to a widespread acknowledgment that additional management of groundwater would be necessary.

Arizona's major unique contribution to water law comes in the form of the Groundwater Management Act of 1980. This act had several major outcomes: the creation of the Arizona Department of Water Resources to manage groundwater resources; the establishment of five Active Management Areas (AMAs) to regulate and control wells and pumping; and the grandfathering of groundwater rights within the Active Management Areas, with senior rights descending from agriculture to development of formerly irrigated land, and finally industry (Pearce 2007; August and Gammage 2007). Perhaps most importantly, the Groundwater Management Act froze the extent of irrigated agriculture within AMAs (Pearce 2007; Graham 2007), which means that the recent development of housing units and commercial real estate on previously irrigated farmland cannot be reversed by creation of new farmland elsewhere in the state. As irrigated agricultural lands shrink, water use declines, since agriculture in Arizona is typically very wasteful of irrigated water and domestic use, per acre, is vastly lower than on farmland.

Two important provisions of the Groundwater Management Act regulate well drilling and housing development. Only licensed drillers are permitted to install wells in Arizona, which allows the Department of Water Resources to enact construction standards as well as monitor groundwater hydrology and water usage patterns statewide (Pearce 2007). Because AMAs must ensure 'safe yield' in terms of groundwater pumping, new housing developments must certify a 100-year "assured water supply" consistent with the overall management goals of the AMA (Pearce 2007). This notification of "assured water supply" only applies to the initial purchaser of a house, however, so the overall long-term impact of this rule on groundwater resources is unclear.

Colorado River Water

Regulation of Colorado River water dates back to 1922, when the Colorado River Compact divided the river into two basins at Lees Ferry, Arizona. Soon afterwards, six of the seven basin states ratified the compact, with Arizona refusing to ratify; Congress soon authorized the Boulder Canyon Project Act of 1928 (Pearce 2007; August and Gammage 2007). By 1931, California water interests had contracted for 5.36 million acre-feet (maf) of the lower basin's 7.5 maf allocation (Pearce 2007). This capture of Colorado River water by California meant that the three other lower basin states could not utilize their full Colorado River allocations.

The post-war development boom and attendant groundwater pumping in Arizona led to a recognition that water sources other than fossil groundwater had to be obtained to secure Arizona's continued growth in population and second homes; others contended that such a new source of 'renewable' surface water would be "essentially a rescue project designed to avert serious disruptions in Arizona's predominantly agricultural economy" (August and Gammage 2007). The requirement of expanded non-groundwater sources caused Arizona to take California to the US Supreme Court over allocations of Colorado River water. In 1964, the US Supreme Court ruled 5-3 in favor of Arizona, and guaranteed Arizona 2.8 maf of Colorado River water annually (August and Gammage 2007; Pearce 2007). In addition to this allocation, the Supreme Court ruling paved the way for the 1968 Congressional approval of the Colorado River Basin Project Act, which ultimately authorized the Central Arizona Project (CAP) to deliver Colorado River water to agricultural and population centers in southern and central Arizona, areas quite distant from the Colorado River. The Colorado River Basin Project Act also awarded junior water rights to the CAP, meaning that all of Arizona's rights to

Colorado River water would be abridged before any water user in California suffers restrictions or reductions in water delivery (Pearce 2007).

The Central Arizona Project itself has had several major impacts on Arizona water policy and law. A new administrative entity, the Central Arizona Water Conservation District, was created to oversee the CAP. Within the CAP subsystem, a hierarchy of water rights is recognized: Native American, municipal/industrial, agricultural, with excess water having the lowest order of protection (August and Gammage 2007).

Because Arizona does not yet use its full Colorado River allocation, and flows in smaller river basins sometimes exceed appropriations, moves have been made to store water underground for future use. Arizona Revised Statutes, title 45, allows 'water banking,' as well as storage and pumping in different parts of the same basin or aquifer, which essentially permits underground transfer of water (Pearce 2007). In addition, water banking allows the state to build up groundwater reserves which can be extracted in times of shortage; this ability extends to nearby states which wish to store Colorado River water in Arizona's aquifers (Pearce 2007).

Effluent

Until recently, effluent was considered a 'nuisance commodity', to be disposed of as cheaply as possible, typically by dumping industrial, agricultural or municipal effluent into waterways (Pearce 2007). As water supplies became ever scarcer, however, the value of effluent became more apparent, and ultimately was subjected to state regulation. In 1989, the Arizona Supreme Court ruled effluent was indeed water rather than some novel substance, but that it did not retain the 'character' of the waters which compose it (groundwater and surface water in varying ratios). This case affirmed the legality of selling and transferring effluent, while at the same time dictating that effluent is not bound by prior appropriation or Groundwater Management Act regulations (Pearce 2007).

Unlike Arizona's surface water or groundwater resources, effluent is not bound by limited supplies. In fact, urban development actually generates additional supplies of this newly-valuable commodity. For the time being, effluent is not being recycled into the municipal drinking water supplies, but is being used for in-stream environmental flows and groundwater recharge, and for irrigation of parks and golf courses.

Environmental Flows

Because Arizona's water policy has been developed largely in the context of the economic interests of Arizona's Five Cs, it does not often account for non-economic interests in and uses of water. However, federal law trumps Arizona law in several important instances. Because water is regulated through such a patchwork of laws and enshrined doctrines, the United States has a history of using the courts, rather than legislative bodies, to apply overarching laws to specific cases. As such, environmental protection has been provided to Arizona's water bodies through the application of federal laws.

Several Federal laws have been used to dictate environmental protections and provide environmental benefits within Arizona. These include the Clean Water Act (1972), the Safe Drinking Water Act (1974), the National Environmental Policy Act (1969), and the Endangered Species Act (1973). Generally, these statutes are enforced through court decisions curtailing certain uses of water or environmental systems.

Some uses of Federal law have led to somewhat novel environmental policies. The Clean Water Act requires that water users hold a permit from the Army Corps of Engineers to alter any 'navigable waters,' including dry washes and ephemeral streams (Glennon 2007). This has created a situation where residents who live near the San Pedro River, an imperiled perennial river in the transborder region of southeastern Arizona and Sonora, are required to have special permits due to

groundwater extraction which has decreased flows on the San Pedro (Glennon 2007). In other cases, the Endangered Species Act is used to designate critical habitats and create species listings which curtail or scale back certain forms of land use, such as cattle grazing within riparian areas. In a state with such a low percentage of riparian areas, and where much of the riparian habitat has been degraded, riparian species are *de facto* endangered.

The federal reserved-rights doctrine could be used to craft environmental protections for in-stream environmental flows, such as on the San Pedro River of Arizona. This river is one of two major rivers that originates in Mexico and flows north into the U.S. When the San Pedro Riparian National Conservation Area (SPRNCA) was created in 1988, the reserved-rights doctrine was assumed to be in effect, with the aims of reserving water to protect valuable riparian areas and ensuring wildlife habitat (Graham 2007). A moratorium was placed on grazing in and near the river, and 12,000 acre-feet of agricultural water were retired in addition to the purchase of nearby conservation easements. Further, a breakpoint in terms of senior and junior rights was established in 1988, with any post-1988 development holding junior groundwater rights to the San Pedro Riparian National Conservation Area (Glennon 2007). Using the federal reserved rights doctrine to limit groundwater pumping in municipalities adjacent to federal land could be the next step for the protection of in-stream environmental flows.

5. The important government agencies in water development and management: their strengths, weaknesses, defining features, and response to droughts: the winners and losers of government water policies

The Arizona-Sonora region has multiple government agencies at the helm of water development and management, including federal, state, city, and binational operations. Arizona's water distribution and regulation is controlled by the regional U.S. Bureau of Reclamation and the state-run Arizona Department of Water Resources (ADWR). There are differing levels of drought preparedness, and in some instances, stark deficits in sanitation and water quality across this region, but all levels of the involved government agencies are engaged in improvement plans to address these concerns and to help buffer these lands against drought.

The U.S. Bureau of Reclamation (BoR), a faction of the Department of the Interior, manages water in the 17 western states of mainland United States. In Arizona, the BoR is primarily responsible for administering diversions of and storage on the Colorado River. In the event of drought, the Bureau of Reclamation has Drought Relief Directives to put into place. The Reclamation States Emergency Drought Relief Act (Title1) was created in 1991 to minimize or mitigate drought damages or losses in Hawaii, the 17 Reclamation States, and the tribes within those states. The Act authorizes conservation activities, temporary construction projects, purchase of water from state or tribal water banks, water loans, and loans for qualifying water users to construct permanent wells or other drought-mitigating structures. Water loans are largely conducted via the Arizona Water Banking Authority, which fills reservoirs with unused Colorado River water to distribute in times of need (United States Bureau of Reclamation 2002).

The Arizona Department of Water Resources enforces and administers Arizona water law, except for the case of water quality, which is managed by the Water Quality Division of the Arizona Department of Environmental Quality (ADEQ). In law suits regarding water rights, the ADWR represents the state of Arizona. Among its other responsibilities are dam inspection and research for means of water augmentation. The ADWR administers a Drought Program whose stated goal is to "Develop mitigation and response strategies to reduce drought impacts on water users" (ADWR 2009b). This is achieved through county-led Local Drought Index Groups which assess the status of the drought according to a Drought Impact Reporting System. The State Monitoring Technical

Committee then confirms the status and severity of this drought, at which point the Local Drought Index Group commences drought mitigation and response efforts. In this way, the ADWR Drought Program develops county response plans to different drought stages and then coordinates with local watershed groups (ADWR 2009d).

One very important player in the border region of Arizona and Sonora is the International Boundary and Water Commission (IBWC), or Comisión Internacional de Límites y Aguas (CILA) in Spanish. This is a joint federal agency, headed by Engineer Commissioners both in El Paso, Texas, and Ciudad Juárez, Sonora. One of the functions of IBWC/CILA is to resolve differences surrounding border and water issues via binational treaties and minutes which, upon approval by both sides, enter into force as binding agreements between the two states (IBWC 2009).

A very important consideration for the feasibility for cross-border sanitation and water-management goals is funding. The Mexican government does supply millions of pesos for wastewater treatment projects, but additional funding comes via the North American Development Bank (NADB) and its sister institution the Border Environment Cooperation Commission (BECC), NAFTA establishments capitalized in equal parts by Mexico and the USA for environmental infrastructure projects along the border. The NADB has contracted over a billion dollars to several programs: The Loan Program, the Border Environment Infrastructure Fund (BEIF), the Solid Waste Environmental Program (SWEP), and the Water Conservation Investment Fund (WCIF). BEIF is the largest recipient of these funds, as it addresses the most critical problem of improving infrastructure for sewage treatment and drinking water sanitation along the border regions of the U.S. and Mexico. Funding for these projects comes primarily from the NADB, along with subsidies from the Comisión Nacional del Agua (CONAGUA) and grants and loans from the EPA. In order to qualify, the proposed work area must be within 100km of the border (on either side), pose a health or ecological risk, and the project must benefit the United States. Projects that benefit both sides will get priority. Dozens of BEIF projects are underway, the vast majority of which address wastewater treatment. Other projects, including the Gila Gravity Main Canal Water Conservation Project of Yuma County, Arizona, and the Water Supply and Distribution Project of Nogales, Sonora, primarily focus on water efficiency and leakage (NADB 2009).

Though many improvements are underway, much of Mexico is being left out of the current development plans. Border cities have an advantage for NADB funding, but all areas further than 100km from the U.S. border do not qualify. Furthermore, rural water infrastructure lags far behind that of cities, and there are several communities without access to water at all. The same can be said of tribal land reservations in Arizona, where tens of thousands of citizens are without plumbing. One of the least hopeful sites in Sonora for meeting water treatment goals is the historic mining town of Cananea, where 70% of surveyed residents rated the water quality in the worst categories. In Cananea, there is no wastewater treatment, unlined landfills, and industrial runoff of sulfates and heavy metal toxins in the water including Cd, Cu, Fe, Mn, Pb, and Zn which exceed permissible limits. These toxins only increase in concentration when water levels drop. When asked about the future water supply (looking forward to the year 2012), Cananea's water managers said the water would run out if current trends continued. Considering Cananea is home to one of the largest copper mines in the world, it is very likely that this water-intensive process will, indeed, continue, leaving a grim prospect for the water quality in this town (Browning-Aiken 2007). This is also a grim prospect for the San Pedro River, which originates in the same basin as the mine. Though (to some degree) federally-protected in Arizona, the river's integrity at its headwaters is threatened by inconsistent management across the border.

6. Major water using sectors and coordination within the current institutional framework

While Arizona's formative years and overarching laws and policies were influenced by the Five Cs, these industries are no longer dominant water users in the state, at least in their original context. The major water users in the state at present are intensively-irrigated agriculture and domestic/municipal applications which together account for over 90% of the state's water consumption. Industrial uses account for about 8% of use, with copper mines being the leading industrial consumer (ADWR 2009a). Viewed from the lens of the consolidated Five Cs (crops, climate and copper), the categories of agriculture, municipal, and industrial water use work well to understand the present impacts of these historic drivers in Arizona.

The agencies and history of water policy discussed above have played an important role in the *de facto* coordination of Arizona's water. The ADWR is currently the organization most responsible for the coordination of the state's water use. ADWR works with the nearly 700 water delivery services within the state to coordinate a wide range of water management issues. Through Active Management Areas (AMAs), planning areas, and the Rural Arizona Watershed Alliance, ADWR tracks water usage, promotes conservation measures, and plays a role in coordinating use (ADWR 2009a).

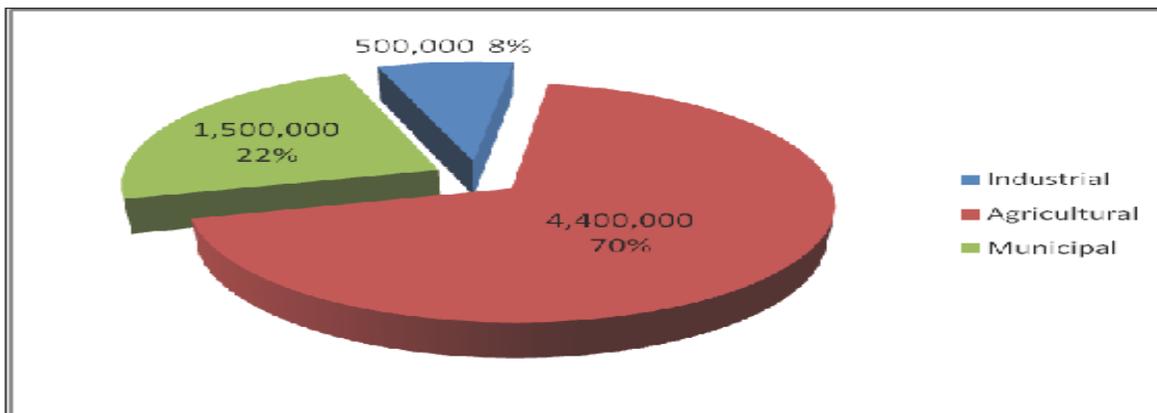


Figure 3: Distribution of Arizona's Water Resources⁶

Agriculture in general still uses 70% of all the water in the state (ADWR 2009a), but there has been a shifting emphasis on the types of crops for which Arizona is famous; cotton has been displaced by lettuce production as the leading agricultural product in terms of farm receipts (UACE 2009). In total, Arizona's agricultural sector consumes almost 5 million acre-feet of water annually, while contributing about \$9.2 billion dollars to the state's economy (UACE 2009).

Citrus and cattle are also losing their economic predominance in the state. Interestingly, and not quite as picturesquely as consumers would like to imagine, half of the state's cattle operations are classed as industrial users of water, since these livestock spend their days on dairy and feedlots instead of the 'open range' (USDA 2009; ADWR 2008). In 2003, these types of operations consumed almost 20,000 acre-feet of water within the AMAs (ADWR 2008). Citrus, too, continues to use large quantities of water, but as an economic contributor, it has been losing ground (USDA 2009; USDA NASS 2008; McKinnon 2009).

Copper mining continues to be a big force in the state and surrounding regions, as well as a substantial user of water. Within the AMAs, mining used 42,090 acre-feet of water in 2003 (ADWR 2008); many of the mines are outside of the AMAs and operate from private wells. As stated above regarding copper mining in Cananea, Sonora, water pollution from mining operations is of great concern. With consideration of this effect, mines 'consume' more water than is ever accounted for.

⁶ ADWR 2009: <http://www.azwater.gov/AzDWR/PublicInformationOfficer/documents/supplydemand.pdf>

The residential development industry that sprang up around the 'ideal' (or rather, 'idealized') climate- has expanded considerably since the original Five Cs imagined Arizona's future as a retirement community or tourist destination. The population of Arizona increased from 120,000 citizens in 1900 (U.S. Census Bureau 1995) to 6.5 million in 2009. Much of the influx occurred during the 1950s, after the advent of air conditioning, which mollified the high temperatures sufficiently for Arizona to appeal to vast numbers of prospective residents. Municipal use of water has grown concurrently. Of the domestic water consumed within the AMAs, the majority of water is used on outdoor landscaping, followed by bathrooms and appliances (ADWR 2008).

Conflicts between urban and rural water users makes easy fodder for local media, but in reality the availability of water allocated to agriculture has allowed Arizona to sustain rapid growth over the last several decades (Pearce 2007). The argument that without agricultural demand, Arizona could support a much greater population is a popular claim in this debate (McKinnon 2005; S. Megdal, personal communication, 5 November 2009).

Coordination between water users is most effective within the AMAs. New agricultural well permits are prohibited in the AMAs, and the transfer of this water to urban uses is itself a type of coordination, given that the water managers are swapping one use for another, and not allowing both. The Assured Water Supply Program limits the number of wells to those where water supply will be assured for 100 years (Pearce 2007). The Adequate Water Supply Program outside of AMAs requires either the developers to certify 100 years of water supply or, where this cannot be assured, disclose the inadequacies to the seller (ADWR 2008). However, this disclosure only needs to occur the first time that a lot is sold, which means that subsequent buyers may not know the limits of the water in their area (C. Woodhouse, personal communication, 5 November 2009).

The CAP has played an important role in the history of water coordination in Arizona, specifically with regards to Native American water rights claims, assured water supply issues, and water banking. 48% of the total CAP allotment goes to Native Americans due to settlements stemming from the federal reserved rights. Much of this water ends up being leased back to cities, but the remainder allows for Native American agriculture to continue to exist alongside ever-expanding urban areas in central Arizona. CAP water is important to issues around assured water supply, because CAP water is designated as assured water. Therefore, housing developments in areas receiving CAP water are able to sidestep this safeguard. Finally, in an attempt to protect itself against the vulnerability inherent in its junior water rights, Arizona has initiated a water banking arrangement with Nevada (August and Gammage 2007, pp.17-20).

None of Arizona's water coordinating entities (AMAs, CAP, utilities) manage with much consideration of anything beyond human users, and Arizona's riparian habitats and dependent species are in grave decline. Consideration of and accounting for ecological requirements has yet to be developed and implemented (S. Megdal, personal communication, 5 November 2009).

7. Main features of the current drought plans and climate change plans

In the early half of the 2000s, the American Southwest was gripped by a relatively short-lived but severe drought. By 2003 the effects of the drought were felt so intensely and broadly that Arizona Governor Janet Napolitano ordered a special taskforce to create a short-term drought plan for implementation in 2004, and also to consider how the state should prepare for and manage drought in the future. The outcome of this effort was the Arizona Drought Preparedness Plan, which contains three major goals:

- Identify the impacts of drought to the various sectors of water uses
- Define the sources of drought vulnerability for water use sectors and outline monitoring programs to alert water users and resource managers of the onset and severity of drought events

- Prepare drought response options and drought mitigation strategies to reduce the impact of drought to water users in Arizona (Governor’s Drought Task Force 2004a)

Although severe, short-term drought was one of the major motivating factors driving the creation of a statewide drought plan in Arizona, several additional factors set the stage for this variety of action. On the whole, Arizona is a very dry state, and around half of the water consumed in the state derives from drought-vulnerable surface water sources, including the Colorado River, the Salt and Gila Rivers, and smaller watersheds within the state. Significantly, 80% of Arizona’s population is served by either the Central Arizona Project or the Salt River Project, both of which deliver surface water.

In its Operational Drought Plan, the state defines drought as “a sustained, natural reduction in precipitation that results in negative impacts to the environment and human activities” (Governor’s Drought Task Force 2004a). Later, drought is recognized to be “more than just a moisture deficit” (*ibid*), because drought can yield differential effects at various spatial and temporal scales, and its impacts depend upon diverse social and physical factors, with divergent effects on different economic sectors and regions. In particular, economic sectors and water users who are reliant on variable surface water sources and who do not have the buffer provided by access to groundwater sources will be more directly impacted by drought. These sectors include grazing, forestry and recreation, particularly recreation centered on water and on wildlife, such as boating or hunting.

Arizona’s Drought Preparedness Plan suggests several strategies for mitigating drought, including the development of additional water storage and water supplies, altering land management decisions, advancing water conservation, and perhaps most importantly, state-level mandates for water conservation and drought response (Governor’s Drought Task Force 2004a). These mandates are typically presented in the form of tables which outline steps to be taken by the state, by water delivery agencies, and by individuals at various levels of drought. One obvious shortcoming of these tables is that while water shortage levels are referred to (Drought Stage: Normal, Abnormally Dry, Moderate, Severe, Extreme), there are no specific definitions of any of these drought stages. In addition, the State lists steps that it “will” do in the case of drought, whereas individuals and utilities merely “need to” take certain steps (Governor’s Drought Task Force 2004a). The irony in this case is that the normative “need to” steps will actually save water; these are material practices which will lead to water conservation and in some cases, drought adaptation. What is striking is that the State has the power to require these steps be taken at certain trigger points, but declines to legislate water conservation, even in the case of drought.

Use of science

When considering historical drought and vulnerabilities, the Governor’s Drought Task Force makes frequent reference to scientific reconstructions of streamflow and wildfire, both of which are strongly correlated to drought. In evaluating the vulnerability of surface water supplies, the Task Force considers a 1000 year tree-ring record of streamflow as well as a tree-ring reconstructed Palmer Drought Severity Index. Fire scars and tree-ring studies were also used to evaluate historical wildfire regimes and their connections to drought (Governor’s Drought Task Force 2004b). The use of paleoecological studies to contextualize contemporary understandings of the historical range of variation in precipitation and temperature is certainly a good strategy.

The Drought Task Force makes no mention of climate change forecasts, however. This lack of attention to forecasting is surprising, because paleoecological data coupled with climate model outputs can give a much better-targeted sense of what Arizona’s future climate will entail, which in turn would be very useful for drought planning. It will also promote a reconsideration of drought vulnerabilities, which differ under divergent climate scenarios.

Assessment of multiple vulnerabilities

As mentioned above, the Governor's Drought Task Force assesses drought vulnerabilities, particularly those stemming from differences in economic sector, region, or activity. The bulk of Arizona's drought plan, however, comes in the form of working group reports which are appended to the plan. These reports cover Tribal issues, municipal and industrial concerns, and commerce and tourism. Additional working group reports focus on environmental health, watersheds, livestock and wildlife considerations, and factors affecting irrigated agriculture or cross-sector impacts (Governor's Drought Task Force 2004a).

Despite all of Arizona's obvious vulnerabilities, in general, the state seems oddly well buffered from drought. The Salt River Project, which delivers water to agricultural, municipal and industrial users in and near Phoenix, has only enacted water restrictions three times in its 106 year existence. And although groundwater pumping has led to ecologically disastrous overdrafting of the aquifers in central and southern Arizona beyond what is recharged through natural infiltration, a vast supply of subsurface water still exists in these aquifers—perhaps upwards of a 200 year supply.

The aim of the statewide drought plan is to craft strategies for mitigation of drought effects and to lessen vulnerabilities to water shortages and the ecological consequences of drought. Although Arizona's drought plan lacks concrete enforcement and has very few associated statutes aimed at yielding tangible action on drought, the drought plan does seem to serve a purpose in terms of positioning the state to take action in the event of severe drought. Certainly, it is encouraging that the conversations and studies which comprise Arizona's Operational Drought Plan have occurred, even without much material action having followed on the publication of the plan.

Certain concrete actions have followed Arizona's drought plan, though. Eight of Arizona's sixteen counties have crafted or contributed to drought impact reports and have generated their own drought plans. In addition, a 2005 statute calls for drinking water providers to produce water supply and conservation plans, as well as to report annual water demand to the Arizona Department of Water Resources (ADWR 2009a). To date, approximately 670 water plans have been received by the Department of Water Resources, although only 65% meet the statutory requirements of the plans (ADWR 2009b).

Conclusion

Arizona needs a new set of Five Cs in order to realistically address the current and future needs of the ecosystems, of which humans are a part. As part of affirming a hydrologically sound desert ethic, we propose a set of new Five Cs:

1. Climate change

Given the evidence that Arizona and the desert southwest are likely to be seriously to severely affected by climate change, with many predictions of continuing and intensifying drought, the state needs to promote realistic future scenarios for water. The dependency on imported water and electricity generated by dams on the Colorado River make Arizona extremely vulnerable to basin-wide shortages. This awareness should be expanded to cover all of Arizona's development plans, and at the very least, instrumental record drought should be incorporated into determinations of 100-year assured water supplies.

2. Coordination (inside and outside of AMAs)

The provisions governing the AMAs and non-irrigation expansion areas are worth replication statewide. Much of Arizona's projected population growth is expected to occur outside the existing AMAs. Current water law monitors new well construction but does little to regulate groundwater pumping outside the AMAs. Moreover, future policy must recognize the connectedness of

groundwater and surface water resources. Continued monitoring, coupled with increased regulation and coordination of water users, will be paramount for assuring Arizona's water sustainability.

3. *Crops (that are arid adapted)*

Arizona's relationship with agriculture need not be all or nothing; the state can continue to produce agricultural goods without such heavy reliance on intensive irrigation. While it may not make continued ecological or economic sense to subsidize thirsty crops like alfalfa or lettuce, there is a long history of growing drought-adapted crops in the arid southwest which rely on less intensive and more sustainable irrigation. If Arizona redefines itself as something other than the nation's January "salad bowl," and focuses instead on native, low-water edible greens, mesquite flour, and cactus fruit, perhaps the nation's interest in Arizona's cuisine can be redefined as well.

4. *Conservation*

As a state which has had to contend with aridity and drought, Arizona could be a leader in establishing demand-side water conservation policies and options for all its citizens. Comparatively progressive conservation measures have been implemented in residential, industrial and agricultural sectors. These efforts, enabled by progressive legislation, are furthered by the prevalence of water-efficient fixtures and advances in graywater use and rainwater harvesting. Even more radical efforts include allowing citizens to install water-saving composting toilets.

Reductions in water consumption should return "surplus" water to environmental flows, rather than allowing further unfettered growth. A hard look at the needs of Arizona's riparian dependent native wildlife and a legal framework that protects what remains of Arizona's in-stream flows on federal, state, and private land are imperative. Consideration must be given to species' needs in the context of future climate-induced pressures.

5. *Consciousness (improved translational science)*

It is apparent that the marketing of Arizona as a place with abundant water has slowed the creation of a sustainable desert ethic. Artificial lakes, private swimming pools, and Arizona's per capita boat-ownership statistics defy the climatic paradigm of the region. Campaigns to encourage a desert ethic and reduce water consumption are necessary actions towards this goal. As the population continues to grow, and if climate change predictions are manifested, water shortages will become commonplace and municipalities will have to scramble to meet demand. Instead of waiting to manage demand during crisis, we propose that Arizona focus on decreasing baseline water demand. Furthermore, establishing communication between the scientific and water management communities is a necessary first step in creating sound management strategies.

These proposed Five Cs are a necessary step for changing the *status quo* of Arizona's water management. Some of these proposals might seem improbable, but they are no more out of place than a Phoenix arising in the Arizona desert. Living within the constraints of a desert climate should be a realistic goal.

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