Desert Water: Paradoxes and Trade-Offs

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The key climate, environment, and resource management issues in the Southwest all revolve around water. From the most remote outpost, seep, or spring to the largest farm, city, or river in the region, the quantity and quality of water is fundamental to the well-being of people, wildlife, ecosystems, rangelands, everything we value. This is true everywhere on earth, but it comes into sharp contrast in the arid southwestern United States and northern Mexico, home to four deserts (Chihuahuan, Sonoran, Mohave, Great Basin), where surface water is scarce, perennial streams are rare, most lakes are man-made, and human population growth and economic activities have increased at rapid rates. This brief essay explores several Arizona water issues, including climate and societal challenges to sustaining water resources in this urbanizing, arid region. The essay is not meant to be comprehensive, but illustrative of the science, history, paradoxes, and trade-offs behind water-related issues addresses by the projects in *Ground|Water*.

REGIONAL WATER ISSUES

The Colorado River, the main source of surface water for southern Arizona, has been called "the hardest working river" (Pulwarty et al. 2005). By the standards of other major continental rivers, the Colorado is quite small. It is about 2.5 times shorter than the Mississippi–Missouri system, and only around one-third the length of the Nile. Its discharge is only one-tenth that of the Nile, one-hundredth that of the Mississippi–Missouri system, and one-thousandth that of the Amazon. The Pacific Northwest's Columbia River, which drains approximately the same area as the Colorado, discharges nearly 40 times the flow of the Colorado at its mouth. Nonetheless, the Colorado is an engine of economic growth and sustainability for major cities such as Las Vegas, Los Angeles, Phoenix, San Diego, and Tucson. For cities such as Phoenix and Tucson, which have depended on groundwater supplies for most of their history, water from the Colorado River is referred to as a renewable water supply.

The Colorado River is supplied primarily by snowmelt from headwater mountain ranges in Wyoming, Utah, and Colorado; 15% of the land surface generates 80% of Colorado River runoff. Snowmelt from these "water towers" of the Southwest feeds an intricate system of dams and diversions that delivers water to farms and urban areas hundreds of miles from the main stem of the river. In the twentieth-century era of dam building in the western United States, the U.S. Bureau of Reclamation developed substantial storage in Lake Powell and Lake Mead, which, together, can store up to four years' worth of Colorado River water supply. These massive reservoirs, the largest man-made lakes in the United States, feed the temporary holding "ponds" of Lake Mohave and Lake Havasu, which are the points of conveyance for water to major downstream agricultural areas, such as the Imperial Valley, and urban areas like Los Angeles, Phoenix, San Diego, and Tucson. To reach Tucson, Colorado River water is lifted over 3,000 feet from Lake Havasu and channeled over 300 miles through the Central Arizona Project canal.

Of course, the Southwest is a region prone to historic multiyear droughts and prehistoric multidecade "megadroughts" (Meko et al. 2007), the likes of which have not been experienced by our technologically advanced, highly urbanized society. A drought which began in the late 1990s rapidly reduced water storage in the great reservoirs of the Colorado River, and put the specter of water shortage, and the prospect of climate change, in the consciousness of many regional water planners and decision-makers. The ongoing drought has also brought home to the public the well-documented fact that the 1922 Colorado River Compact doled out more water to the seven basin states than is available on average, because the data available in 1922 characterized as average what is now known, with a much longer streamflow record, to have been the wettest period on record. Briefly, the River's water resources are overallocated. Concerns over potentially scarce resources and the prospect of shortage, along with a history of Arizona–California legal battles, brought this point home to the state of California, which was forced by the Department of Interior, in 2003, to reduce its historic overuse of Colorado River water supplies. To keep from losing water to California, Arizona has since the 1990s banked Colorado River water underground. This use of surface water, illustrative of the "use it or lose it" mandate of western water law, is one of the many conundrums of the water world explored in *Ground|Water*. Paradoxically, water banking is also a practice advocated to resist potential impacts of future climate change, as it provides a hedge against future shortage.

Another conundrum is that more than 70% of Colorado River water goes to agriculture, an activity considered a "beneficial use," which is a cornerstone of western water law. Desert agriculture is remarkably productive, due to the ability to grow multiple plantings during a single year. However, for rivers such as the Colorado, mounting pressure has been put on surface water supplies from drought, increasing population growth, and demands to reserve or return water to restore and preserve environmental processes. Add climate changes, such as hotter temperatures and increased evapotranspiration, and it is not difficult to envision a future in which there will not be sufficient water for everything to which we have grown accustomed. Society will need to make tough decisions, explicit trade-offs, about the values and uses of water. Paradoxically, the looming crisis of insufficient surface water supplies from the hardest-working river has fostered much more public input into debate and increasingly creative decision making about future management practices, planning, and preparations.

TUCSON: WATER, WATER, EVERYWHERE? ANYWHERE?

One way in which the contributors to *Ground|Water* focused their explorations on the theme of water was to examine the specific situation of Tucson, Arizona. Like other Arizona cities and towns, Tucson has a long history of human habitation, a rapidly increasing population, and an enormous and well-structured history of water development and management accompanied by unfortunate, some would say catastrophic, unintended consequences for surface water and ecosystems. Tucson's water challenges are similar to those throughout the Southwest. History and hydrology show that the cumulative impact of Anglo-American settlement has contributed to the overutilization of surface water resources, the dewatering of streams, aquifer decline, land subsidence, and channel erosion. By 1940, groundwater was being withdrawn at rates greater than natural replenishment (City of Tucson Water Department 2004). By the 1970s, it was recognized that the rapid rate of groundwater pumping, initially by agriculture and later by urban development, threatened groundwater supplies, infrastructure (through subsidence), and water quality.

In 1980, Arizona passed progressive groundwater management legislation that regulates further agricultural development, and well drilling, and requires developers to prove a 100-year water supply for new housing subdivisions. However, these safety valves only apply to around 13 percent of the area of the state—the so-called Active Management Areas (AMAs), of which Tucson is one. Loopholes in both water and development laws allow (a) "wildcat subdivisions" in which large parcels are subdivided in a way that allows the developer to avoid providing some services (e.g., sewer lines) and to use unmonitored groundwater wells, and (b) chicanery, such as skirting the state's assured water supply law (outside of the AMAs only). With the latter, if a parcel is found to have a less than 100-year water supply (i.e., "inadequate water supply"), the developer can proceed with developing the lot, as long as they disclose the inadequate supply finding to the initial sale (Jacobs and Stitzer 2007). If the land changes hands, the seller is not obligated to inform the next buyer of the inadequate supply. State agencies can only issue the initial findings, and have no enforcement capability beyond that. Thus, we have another paradox, this time acknowledgment of a bad situation—unsustainably overpumping groundwater—led to progressive legislation, which has been undermined (to some extent) by legal loopholes embedded in the legislation.

DEWATERING OF LOCAL RIVERS AND STREAMS

Some of the details of Arizona water law were astonishing to the *Ground|Water* participants, even though they may make perfect sense to the legislators and judges who have crafted and interpreted them. When describing these details, one is often left with the feeling that the emperor has no clothes. These facts are in plain sight in the public record, and yet are obscure to many Arizonans. For example, there is the well-known disconnect between surface and groundwater in Arizona water law. Arizona law distinguishes between surface water, subflow (a concept, developed in the late nineteenth century, to describe water moving through underground channels in a way that is connected to surface water), and groundwater, which percolates rather than flows (Glennon 2007; Pearce 2007). The science of hydrology makes no such distinction, noting the important connection between surface and groundwater, but the subflow concept has persisted in water law, to the detriment of substantial surface streams. For example, in the San Pedro River basin southeast of Tucson, new wells drilled in the expanding city of Sierra Vista are capturing water moving underground from the Huachuca Mountains toward the river. Such water, which is not characterized as subflow, can be pumped without restriction, ultimately robbing stretches of the river of water that is much needed to maintain stream continuity during the drought episodes to which the region is prone (Glennon 2007).

THE AGE AND ABUNDANCE OF GROUNDWATER

It is easy to take for granted the abundant groundwater that flows from our faucets and has allowed for the development of large urban settlements and commerce in the desert Southwest. While water is present under the land surface in all areas, it can only be withdrawn in amounts sufficient for use by humans where the hydrology and geology are favorable. Isotope dating studies by USGS researchers show that groundwater in the Tucson Basin is several thousand years old (Bexfield et al. 2011).[1] In only a brief century or so, we have depleted or "mined" a substantial amount of this slow-to-renew resource. This makes groundwater a particularly precious commodity, to be used sparingly, or as a backup supply for sustained droughts. While Arizona has vast quantities of groundwater in storage, depletion of groundwater can result in undesirable local consequences, such as land subsidence (over 20 feet in some parts of Arizona) and capture of flow from nearby streams and springs.

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Like every other western state in the United States, Arizona uses the doctrine of prior appropriation, or "first in time, first in right" to govern surface water diversions. This law "encourages economic development at the expense of treating all activities as equal in value," and thus creates perverse incentives to undertake intensive water diversions (Glennon 2007). The dewatering of streams, which, in the 1800s, seemed like a reasonable price to pay for the economic development of the vast West, is a consequence of this practice. Early Arizona lawmakers also adopted a "reasonable use" doctrine to govern groundwater allocations. Reasonable use allowed unlimited pumping of groundwater as long as the water was put to beneficial use on the land, which, in Robert Glennon's words, "encompasses almost all pumping." As Glennon mentions, these concepts may once have been useful, and the ramifications of developing new water laws could surely be a legal nightmare, but this inertia in the legal system leads to the stark reality of the desiccated riverbeds surrounding Tucson.

THE COLORADO RIVER DELTA

The case of the Colorado River Delta is perhaps the largest and most dramatic example of the trade-offs that have been made between economic and environmental values. Typically, as rivers flow downstream and acquire greater volumes of input from tributary streams, they discharge their greatest volume at their mouths. These mouths often fan out in wide deltas and rich estuarine environments, where freshwater meets ocean water. In the Colorado River system, the history of upstream diversion and legal agreements made initially on the U.S. side of the border treat flow to Mexico, and hence the Colorado River Delta, as an afterthought. Of course, Mexico, too, has opted to value terrestrial economic activity over riparian and estuarine environments by diverting most of its paltry Colorado River allocation for agricultural use in northern Baja California. This has resulted in a situation whereby the river only rarely flows all the way to the ocean, petering out in a now-dry delta littered with the calcic carcasses of the shellfish and marine life that once thrived there.

RIPARIAN AREAS

The Colorado River Delta is a large-scale example of a phenomenon repeated in many rivers throughout the arid Southwest: the desiccation of streambeds and riparian habitat. The local example studied by several of the participants in *Ground|Water* is the dry bed of the Rillito, or "little river." The Rillito, which drains the Santa Catalina and Rincon mountain ranges, seldom flows, except during exceptional thunderstorms or relatively rare multiday rain events. As noted elsewhere in this book, the Rillito has suffered numerous local extirpations of wildlife species, and the loss of much of the cottonwood, sycamore, and mesquite gallery forests and bosques that once lined its banks. The stream dewatering is the result of groundwater mining, which has reduced the stream's baseflow level to beneath the surface. The bulk of riparian forest loss is due to a combination of groundwater drawdown and development priorities in which streamside forests have no place.

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The case of the Rillito, studied closely by *Ground|Water*'s participants, poignantly illustrates the paradoxes and trade-offs associated with desert oasis cities. On the one hand, society, perhaps unwittingly, traded the rich aesthetic and ecological miracle of a perennial stream in the desert for extensive irrigated agriculture, initially, and the economic and social opportunities of a winter haven metropolis, eventually. As part of this trade-off, Tucsonans contribute to the ongoing dewatering of the Delta and the robbery of riparian flows in parts of the Colorado River. Daily we flush the Colorado River down our toilets, or without even a passing nod to the snow-covered headwaters in Wyoming, we pour the Colorado out onto our garden beds. Even the virtuous community gardener eats the Colorado River, or the thousand-year old "fossil" groundwater, in every bite of locally grown lettuce. On the other hand, over one million people and a substantial local commercial economy could not exist here without doing substantially more environmental damage to local ecosystems and aquifers, were it not for the water that we import from the Colorado River.

NOTES

1 Groundwater along stream channels is likely to be substantially younger than groundwater in the central part of the basin.

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