Muddy Waters:

The Mixed Legacy of Policies, Infrastructure and Law in the American West

Bruce E. Cain

The story of western US settlement and economic development is to a considerable degree a water tale. Thriving in this region depended on ensuring that there was an adequate supply of water for the people and businesses that wanted to settle and operate in a more arid and semi-arid region than in the rest of the country. That required figuring out how to transport water from where it was plentiful to where it was scarce and then determining who should get what share of water during prolonged periods of drought. Western water controversies are a paradigmatic example of Harold Lasswell's pithy characterization of politics as "who gets what, when and how."

Many current western water issues and policies embody 19th century legacies. People in the more populated east initially perceived the vast empty lands west beyond the 100th meridian as too arid and inhospitable to support widespread settlement and economic development. Over the course of the 19th century, however, water policy was reconceived as a distribution problem rather than an insuperable scarcity challenge. Water, where it was abundant, could be stored behind dams and reservoirs at high elevations and then transported to by gravity to lower elevations. The Hetch Hetchy system is an exemplar of western water ingenuity. Authorized by the Raker Act in 1913, it uses gravity to transport approximately 260 million gallons of water per day over 160 miles to 2.4 million residents in four Bay area counties. An even more elaborate system of storage, delivery and allocation was established in 1922 to manage and divide the 15-million-acre feet of the Colorado River. The Colorado system's dams and reservoirs continue to serve the needs of residents and businesses in 7 Western States.

With the development of powerful pumps and extensive conveyance systems in the 20th century, water could also be transported up as well as down elevated areas, reaching even more commercial enterprises and homes throughout the West. Irrigation, facilitated by pumps and an appropriative rights doctrine, enabled agriculture to flourish in the arid and semi-arid areas of the West. Together, the massive canals, dams and reservoirs built in this period enabled population growth in areas that would have otherwise never flourished.

However, what was cleverly conceived and constructed in the past eventually became more problematic over time as infrastructure aged and perspectives shifted. The water allocations assigned during a primarily agricultural and mining economic period increasingly clash with the water needs in highly populated urban and suburban communities in the modern era. The heightened ecological concerns of an emergent environmental movement in the 20th century and the political difficulty of raising money in the modern political era for infrastructure have made it harder to repair and replace the dams and reservoirs western states have relied on to date. More frequent and extreme weather challenges due to global warming additionally challenge the adequacy and capacity of existing water infrastructure.

The large gray infrastructure that stored water, enabled navigation and generated electricity throughout the 20th century must be repaired, rebuilt or replaced to meet the current demand for water storage given the prospect of longer droughts. The appropriative rights that incentivized large scale agriculture now interfere with and distort efforts to reallocate water for other uses or to recharge depleted aquifers. The rapid growth of Western cities and suburbs over time has the hardened residential and commercial demand for water even as our capacity to store water declines with aging infrastructure and changing snowmelt conditions in western mountain ranges.

The modern West must now reconcile its 19th and 20th century water policies and infrastructures with 21st century demands and climate circumstances. Yet, the traditional components of the western water system remain in place because they continue to serve important commercial and residential purposes (however imperfectly) and are defended by politically powerful constituencies. I will focus on five problematic legacies that shape current water policy: 1. a water utilization legacy that prioritized water use for agriculture over other uses and environmental concerns; 2. an infrastructure legacy of large, gray and decaying reservoirs and dams that cannot easily be replaced: 3. a water entitlement legacy that complicates efforts to allocate water more efficiently and fairly: 4. a land use legacy that continues to encourage people to live in both water scarce and high flood risk areas; and lastly, 5. a fractured governance legacy that misaligns decision authority with water resource boundaries.

#1. A Water Utilization Legacy

As the US acquired its western lands between 1803 (Louisiana Purchase) and 1898 (the annexation of Hawaii), it increased the nation's climate and topographic heterogeneity. While there are many different climate types in the American West, approximately 40% of the western region is classified as arid or semi-arid, which is very different from the eastern side of the 100th meridian divide. Aridity is essentially a measure of dryness expressed as a ratio of precipitation to evapotranspiration (i.e. water that leaves the surface of the soil or plants). The dryest areas are mostly found in the Southwest deserts and the interior west plains while the wettest are found at high elevations and the northwest. In addition to greater aridity, western as opposed to eastern climate is characterized by more seasonality (little or no rain in the summer) and higher variance between rainy and dry years. All of this means that settlers migrating from the east to the west had to deal with much more variable water resources across both time and space.

For centuries before the arrival of the Europeans, Native American tribes dealt with this variability by moving their settlements when conditions worsened —what we now call strategic retreat. However, the US government in this expansion period was looking to populate and develop its western lands permanently to strengthen and secure their claims on them, which meant building water delivery and storage systems that would solve the problems of distribution over different climate zones and during longer time intervals between precipitation events in the American West. Initially, western infrastructure efforts were predominantly privately financed, but the urgency and expense of creating the infrastructure for extensive growth development during the late nineteenth and early twentieth centuries required the Federal government's financial resources and expertise.

The Corps of Engineers was formed in 1802 followed by the Department of Interior in 1849, the Department of Agriculture in 1862 and the Bureau of Reclamation in 1902. These agencies played a major role in developing the American West both before and then after World War 2, when the there was a second wave of government induced by the Korean, Vietnam and Cold War conflicts. Federal assistance for building western infrastructure generally (e.g. highways, dams, reservoirs, railroads, etc.) was most forthcoming during periods of territorial expansion or military mobilization and then waned by the 1970s when the frontier had long been closed and Pacific Ocean security threats abated.

Water was essential for human consumption of course, but also for agriculture, mining and energy. While artists like John Muir and explorers like John Wesley Powell who visited the West appreciated the beauty of the region's lakes, waterfalls, forests and wildlife, the Federal government was primarily intent on populating and developing the land. Massive amounts of water were used for hydraulic gold mining until the practice was finally banned in 1884. Large corporate farms growing crops like cotton and alfalfa flourished with government subsidized water and state enforced water rights. The premise underlying this activity was that land had value only after it was mixed with labor. In the words of John Locke:

> "Whatsoever then he removes out of the state that nature hath provided, and left it in, he hath mixed his labour with, and joyned to it something that is his own, and thereby makes it his property. …tis labour indeed that puts the difference of value on everything…God may have given the world to men, but in order to enjoy the gift, men have to create property by exercising their creative intelligence and their bodies in physical labor"

This Age of Reason assumption was deeply enmeshed in America's political culture in the 19th century and undergirded the country's expansionist logic,

The assignment of water rights, which will be discussed at greater length later, was a key element in a broader strategy to incentivize natural resource and economic development in the newly acquired western region. To induce people to move into water scarce and more dangerous lands, the government gave ownership rights to the land and the resources on it through a series of bills such as the Homestead Act (1862), the Timber Culture Act (1873), and the Desert Land Act (1877). Unlike timber, however, water cannot be owned in the same way as minerals, trees or plants: it can only be used not possessed for the lifetime of a water molecule, and new water cannot be grown since the amount of water on earth is fixed minus some atmospheric escape. Water has multiple uses: it supports fish and other wildlife and is essential to energy production and other industrial activities. And unlike electrons, water molecules can be aesthetically pleasing. Multiple attributes lead to multiple interests and perspectives, all of which eventually percolates into politics. In the words of Mark Twain (purportedly), "whiskey is for drinking, water is for fighting."

This highly utilitarian view of land and resources diminished the intrinsic and environmental value of water. Early US environmentalist like John Muir staked an opposing view to this position. Small diversions from rivers, lakes and stream for commercial purposes or human consumption do not typically cause much environmental damage, but as the regional population grew and industrial processes became more advanced in the late 19th and first half of the twentieth centuries, water was increasingly stored in large dams and reservoirs. Filling in canyons with massive bodies of stored water destroyed the existing ecosystem. The legacy of wanting to use water to support settlement and commerce created a serious tension with environmental advocates and nonprofit organizations that persist to this day.

Consider the case of the Hetch Hetchy Dam. The construction of the Hetch-Hetchy dam was a harbinger of two contemporary controversies: one over so-called gray infrastructure like dams and reservoirs, and the other on the merits of public versus private ownership of water utilities. Even before the highly destructive 1906 earthquake, San Francisco leaders had qualms about the adequacy of ground and surface water supplies in and near San Francisco and were searching for augmented supplies in the Sierras. The shady land acquisition dealings and extortionist pricing of the private local water companies increased public support for public ownership of the water. The fires that followed the 1906 earthquake, just as in the 2025 LA Wildfires, heightened the importance of ensuring an adequate supply of water for protecting and serving the rebuilding city.

After considering and discarding various alternatives, the SFPUC chose the Hetch-Hetchy valley, which was located inside the boundaries of the recently designated Yosemite National Park (1890). The Hetch Hetchy valley had many advocates for both preservation and recreational use. Camping and hiking had become very popular. While some wanted the Hetch Hetchy Valley preserved for its pure wilderness value, others wanted to promote outdoor recreation, including the Sierra Club which derived revenue from the camping fees. This three-way tension between preservation, conservation (i.e. balancing preservation with utility) and maximum utility (i.e. fill in valley with water that would be transported to the Bay area for consumption and commercial use) has persisted to this day. The restore Hetch-Hetchy movement is alive and well, but to date it has neither persuaded a majority of the SF voters nor the courts.

With the supporting advocacy of several other local Bay Area communities, SF leaders lobbied the Wilson administration and Congress, finally securing passage of the Raker Act in 1913. Even without the formidable obstacles of modern day permitting, it would take until 1923 to complete the construction of the dam itself and another 11 years before the system of tunnels, pipes and reservoirs could deliver water to SF. The engineer they hired, MM O'Shaughnessy, had extensive experience with building tunnels, bridges, reservoirs and rail lines and overseeing other municipal projects. The dam initially had what most people thought at the time had more than enough capacity for SF's and surrounding Bay Area communities' water needs but was subsequently raised in height from 227 to 312 ft in 1938 to increase its reservoir capacity. The project's ambition was apparently partly inspired by the grandeur of Roman Empire water system. In retrospect, the decision to build beyond what the San Francisco needed contributed to the rapid population growth around the Bay. Most of the 26 water agencies in the Bay Area system today get at least some of their water primarily from the Hetch-Hetchy.

Whether the State Water project that was built in segments between 1961 and 1997 to or the huge San Pedro Reservoir in 1971 would or could have eventually provided the necessary water for the Bay Area is a subject of ongoing dispute. The alternatives would likely have been more energy dependent and expensive (i.e. less sustainable) in the long run. Hetch Hetchy water does not require as much cleaning as most stored reservoir water requires because its reservoir is enveloped in a granite canyon in protected Federal land. Moreover, unlike the state water system that uses massive pumps and huge amounts of energy to convey the water over the Tehachapi mountains, the Sierra water flows to the Bay area mostly by gravity. Additionally, the Hetch -Hetchy system produces hydroelectric power, a form of clean energy that is even more valued now that it was then because of the need to reduce carbon emissions. In short, the Hetch-Hetchy legacy is a mixed one: a sustainable exemplar on the one hand and despoiler of natural beauty and habitat on the other.

#2 A legacy of large gray infrastructure

Leaving aside for the moment the trade-off between water for utilization versus water as an environmental good, the legacy of gray infrastructure left modern westerners several contentious issues. The western water infrastructure system is varied and complex. The critical components are very large. According to the National Inventory of dams there are 19,700 "large" dams in the US West (defined as over 8 meters in height with storage capacity at or above 16.2-acre feet). The ten largest reservoirs in the US are in states that are located entirely or at least partially to the west of the100th meridian. The scale of water infrastructure has had socio-economic repercussions. The Hetch-Hetchy dam fostered large scale population and commercial growth throughout the Bay Area counties in the 20th century. The population of the seven Colorado River basin states, enabled by the system of dams and reservoirs along the river-- including the largest reservoir in the US, Lake Mead--grew to ten times its original size between 1920 and 2020.

Despite the formidable size and solidity of these structures, they are vulnerable in various ways. They can fail structurally although infrequently. One estimate suggests that there have been 2543 dam failures in the US for a very low annual rate of .00045. The rate is even lower for concrete as opposed to wooden or earthen dams.[1] Nonethless, dams in general become less safe as they age, and the big dams require large sums of money to be maintained and repaired. This point was demonstrated recently by the failure of the Oroville Dam emergency spillway. Working around the clock, it took a year and half and 1.1 billion dollars to repair the damage.[2] In addition, the storage capacity of reservoirs behind the dams can diminish with the accumulation of silt in them. Removing the silt can be a complex and expensive undertaking with dredging costs typically ranging from 8 to 20 dollars per cubic yard.

A dam's capacity, safety and operations hinge on key assumptions about water supply and demand such as how much water will be needed given future growth and whether climate conditions are changing due to natural or anthropogenic causes. In the case of the Hetch-Hetchy, the implicit premises of the system were that enough snow would continue to accumulate in the mountains during the winter (i.e. a supply assumption about precipitation) and that water from the snowmelt would flow to the reservoirs in the Spring, not during the winter rains (a timing assumption).

Global warming can affect both assumptions. A rise in the average temperature can result in insufficient snowpack in the mountains, especially during extended periods of drought. That alters both the supply of water for consumption and for hydroelectric power (i.e. *a too little water problem*). In the rainy years, larger winter flows followed by lower spring flows can strain the capacity to capture and regulate the flow optimally, (i.e. *a too much water problem*). Other related problems include more extreme flooding and wildfires, both of which can exacerbate sediment and water quality issues. In short, legacy water infrastructure struggle to meet modern climate expectations.

Fixing these problems and replacing existing dam and reservoir infrastructure is not just expensive but complicated by the modern political ambivalence towards gray infrastructure. Environmental groups would like to see more dams removed to restore natural habitat and traditional fish migrations. Some dams are too filled with silt to offer much storage capacity. Consequently, there have been at least 2025 dams removed since 1912, 11% of them large dams.

---

[1] https://www.geosyntec.com/consultants/publications/item/8658-estimated-rates-of-failure-for-dams-in-the-united-states#:~:text=We%20estimate%20that%20there%20have,incomplete%20data%20have%20been%20imputed).

[2] https://water.ca.gov/News/News-Releases/2018/Sept-18/Oroville-Spillways-Construction-and-Cost-Estimate-Update#:~:text=The%20current%20estimate%20for%20emergency,of%20the%20project%20in%202019.

While there are less environmentally harmful ways to store water such as in aquifers or by recycling used water to reduce surface water demand, it must be done at comparably large scale to replace what the legacy gray infrastructure now provides. There have been remarkable achievements in water efficiency in recent years, but that is offset by increased and hardened due to continued economic and residential development in the American West. This is most vividly demonstrated by the urban growth the upper basin of the Colorado River. Strategic retreat from water scarcity is not a political viable option. Limiting further encroachment on water deficient lands is a more realistic option, but by no means easy to accomplish politically.

Aquifers in West have been used traditionally as the backup system by many farmers during drought years when surface water supplies were low. Some of those aquifers can be recharged, but farmers must be incentivized to undertake the expense of doing so. The soil in some aquifers compacts after the water is withdrawn. The soil conditions for potential new aquifer storage are very specific with respect to porosity and the absence of natural contaminants. Even when the land is appropriate for storing water by these criteria, new underground storage in many instances still requires conveying from it where it is stored to where it is needed, which means new piping. With enough money and political will, these problems are solvable. But these conditions have shifted the calculus of water policy now as compared to the 19th and early 20th century. When the West was expanding, water infrastructure led population and commercial growth. Now to a greater degree, existing growth defines the demand for water infrastructure.

Another critical aspect of the earlier water infrastructure legacy in the West is that it was led by the Federal government for reasons of security and economic development. But absent a salient national security threat, it is unclear whether the Federal and state governments will step up in the same way in the modern era.

The most ambitious era of large water infrastructure was between 1900 and 1970. This list of achievements in this period is impressive: in California alone, the Owens River Aqueduct (1913), O'Shaughnessy Dam (1923), Hoover dam (1931), the Central Valley Project (1935), Colorado Aqueduct (1940), Shasta Dam 1944, Delta Mendota Canal (1951), State Water Project (1960), Trinity Dam (1962), California Aqueduct (1966), and Oroville Dam (1968). The immediate postwar WW2 period in California—referred to as the Pat Brown era-- brought aggressive pro-growth policies built around water infrastructure and higher education expansion that were meant to attract new residents.

However, by 1970, a countermovement aimed to slow urban growth that was contributing to increased traffic congestion, smog, and environmental degradation. This curbed the state's appetite for infrastructure led growth. Also in this period, Federal legislation such as National Environmental Policy Act (1969) strengthened environmental review of Federal projects and similar state measures such as CEQA did the same for state and local projects. The Federal government's Clean Water Act (1972) and Endangered Species Act (1973) plus additional new state environmental law such as California Wild and Scenic Rivers Act 1972) put water infrastructure projects under stricter procedural requirements and increased the complexity and delay of permitting times. Modern environmental concerns about the harmful impact of creating large dams and reservoirs reinforced a growing reluctance in Northern California to allow its water to be diverted to the south to enable yet more growth there. This led to the rejection of the peripheral canal in1982 and subsequent squabbling over a Bay Delta settlement. This limits the options for meeting the demand for water to fixing and maintaining existing grey water storage, replacing it with new greener water storage, or expanding water reuse programs.

The large grey infrastructure system relied heavily on state or federal funding for initially building and then continuing to operate and support the various pieces of it. It also created subsidies for agricultural users that created disparities between what residential customers and farmers pay for water. The San Diego County Water Authority, for instance, charges $1929 per acre foot for treated water to its retail customers while farmers in the Imperial Valley pay as little as 20$ per acre foot for Colorado water. The cost of desalinated water is as much as $2367 per acre foot. The Imperial Water district gets 80% of the Colorado River water delivered to California. Historically, the costs to the region's farmers are low because the storage and delivery of water was heavily subsidized by the Federal government. Most recently, to increase water conservation in the lower basin, meet growing demand in the upper basin and accommodate worsening climate conditions, farmers have been offered general financial incentives to conserve water and leave it in the ground. [3]

Subsidies, low and easily forgiven loans, and federally covered crop insurance have encouraged persistent inefficient practices long the Colorado Reiver such as growing low value crops like alfalfa or crops that could be grown in the American south where water is more abundant and climate less arid. The path dependency of growing cotton in dry hot places like Arizona where evapotranspiration and aridity rates are high is illustrative. During the civil war, the blockade of southern cotton incentivized farmers in Arizona to grow cotton for the European market. New strains of cotton developed in North Africa, subsidies and ample groundwater encouraged farmer to get into the cotton growing business. The demand for cotton was boosted during World War 1 as cotton was used for truck tires and airplane wings. By the 1950's all parts of the south were producing 8 billion pounds of cotton per year, much of it for export, but southwestern cotton was able to produce twice as much cotton as the rest of the south because of water irrigation advantage. In doing so southwest farmers used 2 to 4 times more water per acre than their competitors. This inefficiency will likely worsen as droughts become more prolonged due to global warning.[4]

---

[3] https://calmatters.org/commentary/2023/06/colorado-river-deal-west-water/#:~:text=What%20was%20the%20price%20of,taxpayers%20contribute%20$416%20million%20annually.

[4] https://www.scientificamerican.com/article/federal-dollars-are-financing-the-water-crisis-in-the-west/

Residential and commercial customers are hurt by this entrenched arrangement. Squeezed by the expense of paying farmers to pay for their water and the cost of find alternative sources of water, the more heavily populated coastal counties in California have increasingly relied on recycled and desalinated water. Not only is the treatment and delivery of that water expensive, as mentioned earlier, but the fixed charges associated with it are essentially a regressive tax on consumers, which impacts lower income communities especially.

The legacy water infrastructure system cannot be cheaply replaced or easily fixed. Something will have to give in the future as the votes and the money are ultimately not on the farmers side.