Drying of the West

Published: February 2008

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The American West was won by water management. What happens when there's no water left to manage?

By Robert Kunzig

When provided with continuous nourishment, trees, like people, grow complacent.

Tree-ring scientists use the word to describe trees like those on the floor of the Colorado River Valley, whose roots tap into thick reservoirs of moist soil. Complacent trees aren't much use for learning about climate history, because they pack on wide new rings of wood even in dry years. To find trees that feel the same climatic pulses as the river, trees whose rings widen and narrow from year to year with the river itself, scientists have to climb up the steep, rocky slopes above the valley and look for gnarled, ugly trees, the kind that loggers ignore. For some reason such "sensitive" trees seem to live longer than the complacent ones. "Maybe you can get too much of a good thing," says Dave Meko.

Meko, a scientist at the Laboratory of Tree-Ring Research at the University of Arizona, has been studying the climate history of the western United States for decades. Tree-ring fieldwork is hardly expensive—you need a device called an increment borer to drill into the trees, you need plastic straws (available in a pinch from McDonald's) to store the pencil-thin cores you've extracted from bark to pith, and you need gas, food, and lodging. But during the relatively wet 1980s and early '90s, Meko found it difficult to raise even the modest funds needed for his work. "You don't generate interest to study drought unless you're in a drought," he says. "You really need a catastrophe to get people's attention," adds colleague Connie Woodhouse.

Then, in 2002, the third dry year in a row and the driest on record in many parts of the Southwest, the flow in the Colorado fell to a quarter of its long-term average. That got people's attention.

The Colorado supplies 30 million people in seven states and Mexico with water. Denver, Las Vegas, Phoenix, Tucson, Los Angeles, and San Diego all depend on it, and starting this year so will Albuquerque. It irrigates four million acres of farmland, much of which would otherwise be desert, but which now produces billions of dollars' worth of crops. Gauges first installed in the 19th century provide a measure of the flow of the river in acre-feet, one acre-foot being a foot of water spread over an acre, or about 326,000 gallons. Today the operation of the pharaonic infrastructure that taps the Colorado—the dams and reservoirs and pipelines and aqueducts—is based entirely on data from those gauges. In 2002 water managers all along the river began to wonder whether that century of data gave them a full appreciation of the river's eccentricities. With the lawns dying in Denver, a water manager there asked Woodhouse: How often has it been this dry?

Over the next few years Woodhouse, Meko, and some colleagues hunted down and cored the oldest drought-sensitive trees they could find growing in the upper Colorado basin, both living and dead. Wood takes a long time to rot in a dry climate; in Harmon Canyon in eastern Utah, Meko found one Douglas fir log that had laid down its first ring as a sapling in 323 B.C. That was an extreme case, but the scientists still collected enough old wood to push their estimates of annual variations in the flow of the Colorado back deep into the Middle Ages. The results came out last spring. They showed that the Colorado has not always been as generous as it was throughout the 20th century.

The California Department of Water Resources, which had funded some of the research, published the results as an illustrated poster. Beneath a series of stock southwestern postcard shots, the spiky trace of tree-ring data oscillates nervously across the page, from A.D. 762 on the left to 2005 on the right. One photo shows the Hoover Dam, water gushing from its outlets. When the dam was being planned in the 1920s to deliver river water to the farms of the Imperial Valley and the nascent sprawl of Los Angeles, the West, according to the tree rings, was in one of the wettest quarter centuries of the past millennium. Another photo shows the booming skyline of San Diego, which doubled its population between 1970 and 2000—again, an exceptionally wet period along the river. But toward the far left of the poster, there is a picture of Spruce Tree House, one of the spectacular cliff dwellings at Mesa Verde National Park in southwestern Colorado, a pueblo site abandoned by the Anasazi at the end of the 13th century. Underneath the photo, the graph reveals that the Anasazi disappeared in a time of exceptional drought and low flow in the river.

In fact, the tree rings testified that in the centuries before Europeans settled the Southwest, the Colorado basin repeatedly experienced droughts more severe and protracted than any since then. During one 13-year megadrought in the 12th century, the flow in the river averaged around 12 million acre-feet, 80 percent of the average flow during the 20th century and considerably less than is taken out of it for human use today. Such a flow today would mean serious shortages, and serious water wars. "The Colorado River at 12 million acre-feet would be real ugly," says one water manager.

Unfortunately, global warming could make things even uglier. Last April, a month before Meko and Woodhouse published their latest results, a comprehensive study of climate models reported in *Science* predicted the Southwest's gradual descent into persistent Dust Bowl conditions by mid-century. Researchers at the National Oceanic and Atmospheric Administration (NOAA), meanwhile, have used some of the same models to project Colorado streamflow. In their simulations, which have been confirmed by others, the river never emerges from the current drought. Before mid-century, its flow falls to seven million acre-feet—around half the amount consumed today.

The wet 20th century, the wettest of the past millennium, the century when Americans built an incredible civilization in the desert, is over. Trees in the West are adjusting to the change, and not just in the width of their annual rings: In the recent drought they have been dying off and burning in wildfires at an unprecedented rate. For most people in the region, the news hasn't quite sunk in. Between 2000 and 2006 the seven states of the Colorado basin added five million people, a 10 percent population increase. Subdivisions continue to sprout in the desert, farther and farther from the cities whose own water supply is uncertain. Water managers are facing up to hard times ahead. "I look at the turn of the century as the defining moment when the New West began," says Pat Mulroy, head of the Southern Nevada Water Authority. "It's like the impact of global warming fell on us overnight."

In July 2007 a few dozen climate specialists gathered at Columbia University's Lamont-Doherty Earth Observatory to discuss the past and future of the world's drylands, especially the Southwest. Between sessions they took coffee and lunch outside, on a large sloping lawn above the Hudson River, which gathers as much water as the Colorado from a drainage area just over a twentieth the size. It was overcast and pleasantly cool for summer in New York. Phoenix was on its way to setting a record of 32 days in a single year with temperatures above 110°F. A scientist who had flown in from the West Coast reported that he had seen wildfires burning all over Nevada from his airplane window.

On the first morning, much of the talk was about medieval megadroughts. Scott Stine of California State University, East Bay, presented vivid evidence that they had extended beyond the Colorado River basin, well into California. Stine works in and around the Sierra Nevada, whose snows are the largest source of water for that heavily populated state. Some of the runoff drains into Mono Lake on the eastern flank of the Sierra. After Los Angeles began diverting the streams that feed Mono Lake in the 1940s, the lake's water level dropped 45 vertical feet.

In the late 1970s, tramping across the newly exposed shorelines, Stine found dozens of tree stumps, mostly cottonwood and Jeffrey pine, rooted in place. They were gnarled and ancient looking and encased in tufa—a whitish gray calcium carbonate crust that precipitates from the briny water of the lake. Clearly the trees had grown when a severe and long-lasting drought had lowered the lake and exposed the land where they had taken root; they had died when a return to a wetter climate in the Sierra Nevada caused the lake to drown them. Their rooted remains were now exposed because Los Angeles had drawn the lake down.

Stine found drowned stumps in many other places in the Sierra Nevada. They all fell into two distinct generations, corresponding to two distinct droughts. The first had begun sometime before 900 and lasted over two centuries. There followed several extremely wet decades, not unlike those of the early 20th century. Then the next epic drought kicked in for 150 years, ending around 1350. Stine estimates that the runoff into Sierran lakes during the droughts must have been less than 60 percent of the modern average, and it may have been as low as 25 percent, for decades at a time. "What we have come to consider normal is profoundly wet," Stine said. "We're kidding ourselves if we think that's going to continue, with or without global warming."

No one is sure what caused the medieval megadroughts. Today Southwestern droughts follow the rhythm of La Niña, a periodic cooling of the eastern equatorial Pacific. La Niña alternates every few years with its warm twin, El Niño, and both make weather waves around the globe. A La Niña cooling of less than a degree Celsius was enough to trigger the recent drought, in part because it shifted the jet stream and the track of the winter storms northward, out of the Southwest. Richard Seager, of Lamont, and his colleagues have shown that all the western droughts in the historical record, including the Dust Bowl, can be explained by small but unusually persistent La Niñas. Though the evidence is slimmer, Seager thinks the medieval megadroughts too may have been caused by the tropical Pacific seesaw getting stuck in something like a perpetual La Niña.

The future, though, won't be governed by that kind of natural fluctuation alone. Thanks to our emissions of greenhouse gases, it will be subject as well to a global one-way trend toward higher temperatures. In one talk at Lamont, climate theorist Isaac Held, from NOAA's Geophysical Fluid Dynamics Laboratory in Princeton, gave two reasons why global warming seems almost certain to make the drylands drier. Both have to do with an atmospheric circulation pattern called Hadley cells. At the Equator, warm, moist air rises, cools, sheds its moisture in tropical downpours, then spreads toward both Poles. In the subtropics, at latitudes of about 30 degrees, the dry air descends to the surface, where it sucks up moisture, creating the world's deserts—the Sahara, the deserts of Australia, and the arid lands of the Southwest. Surface winds export the moisture out of the dry subtropics to temperate and tropical latitudes. Global warming will intensify the whole process. The upshot is, the dry regions will get drier, and the wet regions will get wetter. "That's it," said Held. "There's nothing subtle here. Why do we need climate models to tell us that? Well, we really don't."

A second, subtler effect amplifies the drying. As the planet warms, the poleward edge of the Hadley cells, where the deserts are, expands a couple of degrees latitude farther toward each Pole. No one really knows what causes this effect—but nearly all climate models predict it, making it what modelers call a robust result. Because the Southwest is right on the northern edge of the dry zone, a northward shift will plunge the region deeper into aridity.

As the meeting neared its close, Held and Seager stood out on the lawn, discussing Hadley cells and related matters through mouthfuls of coffee and doughnuts. The two men had lately become collaborators, and a few months before had published with colleagues the sobering *Science* paper analyzing the results of 19 different simulations done by climate modeling groups around the world. They then averaged all these results into an "ensemble." The ensemble shows precipitation in the Southwest steadily declining over the next few decades, until by mid-century, Dust Bowl conditions are the norm. It does not show the Pacific locked in a perpetual La Niña. Rather, La Niñas would continue to happen as they do today (the present one is expected to continue at least through the winter of 2008), but against a background state that is more profoundly arid. According to the ensemble model, the descent into that state may already have started.

People are not yet suffering, but trees are. Forests in the West are dying, most impressively by burning. The damage done by wildfires in the U.S., the vast majority of them in the West, has soared since the late 1980s. In 2006 nearly ten million acres were destroyed—an all-time record matched the very next year. With temperatures in the region up four degrees F over the past 30 years, spring is coming sooner to the western mountains. The snowpack—already diminished by drought—melts earlier in the year, drying the land and giving the wildfire season a jump start. As hotter summers encroach on autumn, the fires are ending later as well.

The fires are not only more frequent; they are also hotter and more damaging—though not entirely because of climate change. According to Tom Swetnam, director of the University of Arizona tree-ring lab, the root cause is the government's policy, adopted early in the 20th century, of trying to extinguish all wildfires. By studying sections cut from dead, thousand-year-old giant sequoias in the Sierra Nevada and from ponderosa pines all over Arizona and New Mexico, Swetnam discovered that most southwestern forests have always burned often—but at low intensity, with flames just a few feet high that raced through the grasses and the needles on the forest floor. The typical tree bears the marks of many such events, black scars where flames ate through the bark and perhaps even took a deep wedge out of the tree, but left it alive to heal its wound with new growth. Suppressing those natural fires has produced denser forests, with flammable litter piled up on the floor, and thickets of shrubs and young trees that act as fire ladders. When fires start now, they don't stay on the ground—they shoot up those ladders to the crowns of the trees. They blow thousand-acre holes in the forest and send mushroom clouds into the air.

One day last summer, Swetnam took a few visitors up Mount Lemmon, just north of Tucson, to see what the aftermath of such events looks like. In May 2002 the Bullock fire roared up the northeast slope of Mount Lemmon, consuming 30,000 acres. Firefighters stopped it at the Catalina Highway, protecting the village of Summerhaven. But the very next year, the Aspen fire started on the slope just below the village, destroying nearly half of the 700-odd houses in Summerhaven and burning 85,000 acres, all the way down to the outskirts of Tucson. The entire mountainside beyond the village remains covered with the gray skeletons of ponderosa pines, like one big blast zone. "Ponderosa pine is not adapted to these crown fires," Swetnam said, contemplating the site from the scenic overlook above the village. "It has heavy, wingless seeds that don't go very far. When you get a large hole like this, it will take hundreds of years to fill in from the edges."

Mount Lemmon's forests are also experiencing a slower, broader change. The Catalina Highway starts out flat, at an altitude of 2,500 feet in the Sonoran Desert, with its saguaros and strip malls. As the road leaves the last of Tucson behind, it climbs steeply through the whole range of southwestern woodland ecosystems—first scrub oak, then piñon and juniper, then ponderosa pine and other conifers, until finally, after less than an hour and a climb of 7,000 feet, you reach the spruce and fir trees on the cool peak. There is a small ski area there, the southernmost in the United States, and its days are certainly numbered.

As Swetnam explained, the mountain is one of an archipelago of "sky islands" spread across southeastern Arizona, New Mexico, Texas, and into Mexico

—mountains isolated from one another by a sea of desert or grassland. Like isles in the ocean, these islands are populated in part by endemics—species that live nowhere else. The sky-island endemics are cool- and wet- loving species that have taken refuge on the mountaintops since the last ice age. They are things like the corkbark fir, or the endangered red squirrel that lives only on nearby Mount Graham. Their future is as bleak as that of the ski area. "They'll be picked off the top," said Swetnam. "The islands are shrinking. The aridity is advancing upslope."

All over the Southwest, a wholesale change in the landscape is under way. Piñons and scrubbier, more drought-resistant junipers have long been partners in the low woodlands that clothe much of the region. But the piñons are dying off. From 2002 to 2004, 2.5 million acres turned to rust in the Four Corners region alone. The immediate cause of death was often bark beetles, which are also devastating other conifers. The Forest Service estimates that in 2003, beetles infested 14 million acres of piñon, ponderosa, lodgepole pine, and Douglas fir in the American West.

Bark beetles tend to attack trees that are already stressed or dying from drought. "They can smell it," says Craig Allen, a landscape ecologist at Bandelier National Monument in the Jemez Mountains of New Mexico. Global climate change may be permanently teasing the piñons and junipers apart, and replacing piñon-juniper woodland with something new. At Bandelier, Allen has observed that junipers, along with shrubs such as wavyleaf oak and mountain mahogany, now dominate the beetle-ravaged landscape: pockets of green gradually spreading beneath a shroud of dead piñons.

Just as there are global climate models, there are global models that forecast how vegetation will change as the climate warms. They predict that on roughly half of Earth's surface, something different will be growing in 2100 than is growing there now. The models are not good, however, at projecting what scientists call "transient dynamics"—the damage done by droughts, fires, and beetle infestations that will actually accomplish the transformation. Large trees cannot simply migrate to higher latitudes and altitudes; they are rooted to the spot. "What happens to what's there now?" Allen wonders. "Stuff dies quicker than it grows."

Over the next few decades, Allen predicts, people in the Southwest will be seeing a lot of death in the old landscapes while waiting for the new ones to be born. "This is a dilemma for the Park Service," he says. "The projections are that Joshua trees may not survive in Joshua Tree National Park. Sequoias may not survive in Sequoia National Park. What do you do? Do you irrigate these things? Or do you let a 2,000-year-old tree die?"

While the trees die, the subdivisions proliferate. "Our job was to entice people to move to the West, and we did a darn good job," says Terry Fulp, who manages water releases at Hoover Dam. The federal Bureau of Reclamation built the dam in the 1930s primarily to supply the vegetable farms of the Imperial Valley and only secondarily to supply the residents of Los Angeles. Farmers had first claim to the water—they still do—but there was plenty to go around. "At Lake Mead, we basically gave the water away," says Fulp. "At the time, it made perfect sense. There was no one out here." After Reclamation built Hoover and the other big dams, more people came to the desert than anyone ever expected. Few of them are farmers anymore, and farming, crucial as it is to human welfare, is now a small part of the economy. But it still uses around three-quarters of the water in the Colorado River and elsewhere in the Southwest.

In the wet 1920s, as the dam was being planned, seven states drew up the Colorado River Compact to divvy up 15 million acre-feet of its water. California, Nevada, and Arizona—the so-called Lower Basin states—would get half, plus any surplus from the Upper Basin states of Wyoming, Colorado, New Mexico, and Utah. The compact also acknowledged Mexico's rights to the water. Surpluses were almost always on hand, because the Upper Basin states have never fully used the 7.5 million acre-feet they are entitled to under the compact. They are only entitled to use it, in fact, if in so doing they don't prevent the Lower Basin states from getting their 7.5 million—the compact is unfair that way. But in the wet 20th century, it didn't seem to matter.

In 1999 both Lake Mead and Lake Powell—created in 1963 upstream of Lake Mead to ensure that the Upper Basin would have enough water even in drought years to meet its obligation to the Lower Basin—were nearly full, with 50 million acre-feet between them. Two years later, representatives of the states in the basin completed long and difficult negotiations with the Bureau of Reclamation on new guidelines for dividing up the surpluses from Lake Mead. Then came the drought. Both lakes are now only half full. "Those guidelines are almost a joke now," says the Southern Nevada Water Authority's Pat Mulroy. "All of a sudden, seven states that had spent years in surplus discussions had to turn on a dime and start discussing shortages."

Mulroy, a crisp, tanned, fiftysomething blonde with a tailored look and a forceful personality, has run the Las Vegas water district since 1989. During that time she has watched the area's population growth consistently outstrip demographic projection. The population is almost two million now, having grown by 25 percent during the drought years; Mulroy is convinced it will go to three million. Before the drought, she and her colleagues nevertheless thought their water supply, 90 percent of it from Lake Mead, was safe for 50 years. In 2002 they were celebrating the opening of a second water intake from Lake Mead, 50 feet lower than the old one, which more than doubled their pumping capacity. Now they are scrambling to insert a third "straw" even deeper into the sinking lake. Las Vegas is also trying to reduce its dependence on the Colorado. The SNWA is exercising water rights and buying up ranches in the east-central part of the state. It plans to sink wells and tap groundwater there and pump as much as 200,000 acre-feet of it through a 250-mile pipeline to the city. There is considerable local opposition, of course, and an environmental impact statement must be prepared—but there is "zero chance," Mulroy says grimly, that the pipeline won't be built.

Other southwestern cities are also realizing their vulnerability to drought. Phoenix, hellish as it is in summer and bisected by the dry bed of the Salt River, is better off than most—for the moment. "In 2002 Phoenix was virtually the only city in the Southwest that had no mandatory restrictions," says Charlie Ester, water resources manager at the Salt River Project in Phoenix. "We didn't need them." Phoenix pumps groundwater whenever it needs to, though it is under a state mandate to stop depleting the aquifer. And it gets a little over a third of its water from the Colorado River via the Central Arizona Project, a 336-mile-long canal. But the Salt River remains its biggest source. The riverbed is dry in the city because the SRP has half a dozen dams in the mountains north and east of the city, which convert the Salt and its tributary, the Verde, into chains of terraced lakes.

Phoenix would thus seem to possess that holy grail of water managers: a diversified portfolio. But Ester was still disconcerted to see his lake levels dropping in the drought, until they were less than half full. After he called the tree-ring lab, Dave Meko and climatologist Katie Hirschboeck looked into the tree-ring records for the Salt and Verde Rivers' watersheds.

"They found they were virtually identical," Ester says. "There were only three years out of 800 where the Colorado was wet and the Salt was dry or vice versa. What that means is, if we have a bad drought in Arizona, and the Salt dries up, we can't rely on the Colorado to bail us out. So what are we going to do? Well, we're going to hurt. Or move."

Since the Hoover Dam was built, there has never been a water shortage on the Colorado, never a day when there was simply not enough water in Lake Mead to meet all the downstream allocations. Drought, and a realistic understanding of the past, have made such a day seem more imminent. Under the pressure of the drought, the seven Colorado basin states have agreed for the first time on how to share prospective shortages. Arizona will bear almost all the pain at first, because the Central Arizona Project, which came on line in 1993, has junior rights. Nevada will lose only a small percentage of its allotment.

Meanwhile California would give up nothing, at least until Lake Mead falls below 1,025 feet, nearly 200 feet below "full pool." At that point, negotiations would resume. According to Bureau of Reclamation calculations, a return of the 12th-century drought would force Lake Mead well below that level, perhaps even to "dead pool" at 895 feet—the level at which water no longer flows out of the lake without pumping. Reclamation officials consider this extremely unlikely. But their calculations do not take into account the impact of global warming.

Every utility in the Southwest now preaches conservation and sustainability, sometimes very forcefully. Las Vegas has prohibited new front lawns, limited the size of back ones, and offers people two dollars a square foot to tear existing ones up and replace them with desert plants. Between 2002 and 2006, the Vegas metro area actually managed to reduce its total consumption of water by around 20 percent, even though its population had increased substantially. Albuquerque too has cut its water use. But every water manager also knows that, as one puts it, "at some point, growth is going to catch up to you."

Looking for new long-term sources of supply, many water managers turn their lonely eyes to the Pacific, or to deep, briny aquifers that had always seemed unusable. Last August, El Paso inaugurated a new desalination plant that will allow the city to tap one such aquifer. The same month, the Bureau of Reclamation opened a new research center devoted to desalination in Alamogordo, New Mexico. The cost of desalination has dropped dramatically—it's now around four dollars per thousand gallons, or as little as $1,200 per acre-foot—but that is still considerably more than the 50 cents per acre-foot that the Bureau of Reclamation charges municipal utilities for water from Lake Mead, or the zero dollars it charges irrigation districts. The environmental impacts of desalination are also uncertain—there is always a concentrated brine to be disposed of. Nevertheless, a large desalination plant is being planned in San Diego County. In Las Vegas, Mulroy envisions one day paying for such a plant on the coast of California or Mexico, in exchange for a portion of either's share of the water in Lake Mead. "The problem is, if there's nothing in Lake Mead, there's nothing to exchange," she says.

A more obvious solution for cities facing shortages is to buy irrigation water from farmers. In 2003 the Imperial Irrigation District was pressured into selling 200,000 of its three million acre-feet of Colorado water to San Diego, as part of an overall deal to get California to stop exceeding its allotment. San Diego paid nearly $300 per acre-foot for water that the farmers in the Imperial Valley get virtually for free. The government favors such market mechanisms, says the Bureau of Reclamation's Terry Fulp, "so people who really want the water get it." At that price, the irrigation water in the Imperial Valley is worth nearly as much as its entire agricultural revenue, which is around a billion dollars a year. But not everyone favors drying up farms so that more water will be available for sub-divisions. The valley is one of the poorest regions in California, yet the richest farmers stand to benefit most from the sale. Many more people fear the loss of jobs and, ultimately, of a whole way of life.

The West was built by dreamers. The men who conceived Hoover Dam were, in the words beneath a flagpole on the Nevada side, "inspired by a vision of lonely lands made fruitful." As the climate that underpinned that expansive vision vanishes, the vision needed to replace it has not yet emerged. In a drying climate, the human ecosystems established in a wetter one will have to change—die and be replaced by new ones. The people in the Southwest face the same uncertain future, the same question, as their forests: What happens to the stuff that's there now?

In the second half of the 13th century, as a drying trend set in, people who had lived for centuries at Mesa Verde moved down off the mesa into the canyons. They built villages around water sources, under overhangs high up in the walls of the cliffs, and climbed back up the cliffs to farm; their handholds in the rock are still visible. Some of the villages were fortified, because apparently their position on a cliff face was not defense enough. Those cliff dwellings, abandoned now for seven centuries but still intact and eerily beautiful, are what attract so many visitors today. But they are certainly not the product of an expansive, outward-looking civilization. They are the product of a civilization in a crouch, waiting to get hit again. In that period, the inhabitants of the Mesa Verde region began carving petroglyphs suggesting violent conflict between men armed with shields, bows and arrows, and clubs. And then, in the last two or three decades of the century, right when the tree rings record one of the most severe droughts in the region, the people left. They never came back.