2,000 YEARS OF WATER WOES

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It is too easy to take our surroundings, natural and cultural, for granted. Only a few years ago, drought seemed a rare threat in our lives. Much of the 1980s and several years in the 1990s were very wet years, and a vision of water rationing and vast die-offs of piñon trees would have seemed apocalyptic. As we face the possibility of a long-term change in our climate, it seems useful to step back and look at how stable (and unstable) our southwestern climate has been. What were the water crises of the past, and as importantly, what did people do about them?

Archaeologists study climate with almost as much interest as we study ancient peoples. In the Southwest, we have tremendous but imperfect research tools, including tree-ring records, pollen cores, packrat middens, and even the settlement choices of Native American ancestors. Moisture (rain and snow) is the most obviously important dimension of climate, but heat and cold play significant roles as well. Seasonal moisture patterns are as important as total annual precipitation, and the past 2,000 years have been anything but stable in all of these factors. The last two millennia are especially relevant in the sense that we have become more and more reliant on agriculture during that period. Although we now can move foods across the continent and even between continents, crop success is tied to climate factors, regardless of the source.

Drought reflects a shortage of water in a relative sense. A year or two of too little rainfall, or perhaps even ten or twenty years, can be considered a drought but only when compared to a longer term pattern where stability is maintained over tens to hundreds of years. If the baseline weather pattern is changing over tens to hundreds of years, then climate change is involved as nature provides a new, albeit temporary, equilibrium. Unfortunately, only hindsight can reliably distinguish between the onset of climate change and an episode of drought. The relative quality of drought also involves the quality of moisture—a lot of snow that melts slowly or many gentle rains are far better than a single deluge, most of which runs off rather than soaking in. In addition, the time of year that moisture arrives is important. The arrival of winter snows, spring rains, and summer thundershowers needs to coincide with the physiological needs of plants or crop failure is a distinct possibility.

Tree rings are great for detecting past droughts, but longer term patterns are often lost in the maze of statistical manipulations used to compare ring widths. Pollen rain, as a measure of vegetation, is a more sensitive measure of long-term climate change, but pollen rain is a complex mixture of regional and local contributions of pollen whose interpretation is less than self-evident. Though packrat middens provide datable accumulations of local vegetation, useful in confirming what types of plants were growing on the local landscape, the rodents' middens are preserved only sporadically and offer far from a continuous record of vegetation and climate change.

What some see as the first great drought of the 21st century doesn't compare to those of the past, no matter how many thirsty, weakened piñon are sadly lost to the bark beetle.

Despite the individual weaknesses, by putting all of this information together we can build a picture of both short term and long term climatic variability that is both detailed and robust. The temporal variation is coupled with high geographic variation, such that no single reconstruction is accurate for all the Southwest. Droughts have been common but were usually of short duration. At times, periods of persistently dryer and warmer climate occurred that were followed by centuries of relatively wetter climate with reliable monsoon seasonal patterns. A few long droughts are documented in tree-ring records, and archaeologists believe that they can detect human responses to some but not to others. Geographic contrasts are also evident during the few truly dramatic periods of climate change, in which some areas suffered drought while others benefited from increased rainfall, making the picture more complicated.

Archaeologists have pieced together a remarkably detailed mosaic of the past 2,000-plus years of human innovation and adaptation in the Southwest. Terms such as "marginal" and "precarious" often are used to describe prehistoric southwestern cultures as a whole, emphasizing the limitations that the semiarid environment has placed on the conditions of existence. This pessimistic view is countered by the remarkable stability and creativity of what can be called the Puebloan Lifeway—a way of life rooted in a dependence on farming. Technological and social tools coped with the environmental marginality to the degree that prolonged droughts and changes in climate caused major lifestyle changes in only in a few instances over the past 2,000 years.

As in most of the world's semiarid regions, the two most basic adaptations to southwestern climate were diversification and crop storage. Diversification worked as long as population levels were small. A poor year for crops would not necessarily be a bad year for piñon nuts or grass seed, so a family would simply turn more to hunting and gathering until the next year. As populations grew, diversification was more difficult. Instead, most drought effects could be ameliorated through planting and stockpiling strategies that sought to maintain at least three years of corn in each family storeroom. This buffer was maintained at the family rather than community level, ensuring that decision-making was quick and accurate. Intra-community sharing of food occurred as needed with the help of periodic feasting, and regional social relationships were maintained by exchange of non-food items. Such trade anticipated economic crises in which either food or, more often, people needed to move

Head gates that were built A.D. 1000–1100 still capture and channel water at Peñasco Blanco, when there is water to be caught and stored. Field photography by Wolcott Toll, Office of Archaeological Studies.

over longer distances for either short or long periods.

Family mobility was long a means of dealing with prolonged droughts and major climate changes. During the earliest centuries of agricultural dependence, settlements tended to be small, rarely composed of more than a handful of families. Loosely clustered neighborhoods of farmsteads were more common than villages, and villages of as many as a hundred families were rare. Even within villages, decisions to move often appear to have rested with the family, and the few movements of entire villages are notable. With few exceptions (such as Chaco Canyon), capital investments in homes were small, allowing residences to be abandoned with little sense of loss. For much of the past 2,000 years, homes routinely were abandoned within a generation or less, establishing a basic rhythm of constant adjustment and movement that could be over short or long distances. When capital investments did take place, they seem to have been associated with periods of stable climate—occasions when the three-year buffer strategy could have resulted in substantial surpluses when expected droughts did not occur.

Water management was a critical part of coping with climatic limitations. The need to secure reliable supplies of drinking and cooking water were inherent in settlement decisions. Rarely did families reside more than a casual walk from a stream or spring. Shallow wells were dug in streambeds to tap ground water, and bedrock cisterns (natural and improved) captured and held seasonal precipitation. Well-known examples of large natural pools are found at Acoma Pueblo and El Morro National Monument where hundreds of thousands of gallons of water could be impounded. Reservoirs for the accumulation of domestic water, complete with feeder diversion ditches, were built near some large villages, but these are rare and appear to result from particular crises. Near some small communities, earthen or stone barriers were built across arroyos, and the channel bottom was deepened to catch and store drinking water.

As population size across the Southwest grew with the advent of agriculture, the supply of sufficient water for crops became ever more important. The seasonal pattern of moisture availability was a constant background in normal years: Winter snows provide the soil moisture necessary for germination and early plant growth, and the monsoon rains of July arrive just in time to keep the young plants alive and then carry the crop through to harvest in the fall. Simple techniques aided effective water management and three basic strategies appeared—conservation, collection, and diversion. Water conservation techniques were generally uncomplicated. For example, instead of plowing, farmers made holes with a digging stick and put a few seeds in each hole. When left undisturbed, the natural soil crust retards soil moisture evaporation, and the ground surface is less susceptible to erosion. By planting deeply, the seeds benefit immediately from soil moisture, particularly where sandy soils overlay clayey soils: The clay acts as a basin where water collects and the sand prevents evaporation.

Water conservation practices were augmented by a variety of water collection and diversion techniques generally known as water harvesting. Farming in the vicinities of *cienegas* and springs was an early strategy, and stream irrigation was in use in southern Arizona by 1000 B.C. These early efforts ultimately led to the complex canal irrigation systems of the Hohokam culture, a system that was remarkably successful until floods and falling water tables destroyed the head gates in the 1300s. Recently, simple ditches have also been found in the upland settings around Zuni. Dated to the last century B.C., these are the earliest known ditches in the puebloan highlands and show that the capture and redirection of runoff was used much earlier than previously suspected.

The harvesting and distribution of runoff from individual rainstorms was far more common than actual canal irrigation. Check dams, low terraces, and rock-bordered growing plots were used to slow runoff from showers, holding the moisture in the field locations long enough for it to soak into the soil. A common example is the *akchin* field, derived from the name for the Tohono O'odham and Pima people of southwestern Arizona. Though this type of field is found in their homeland, its use is also well-documented around the pueblo communities of the Southwest, particularly at Hopi. These fields are placed at the mouths of arroyos or on alluvial fans where runoff is slowed and spread out by small brush or earthen dams. In contrast to this simple method, the use of water harvesting technology became quite sophisticated in other areas. In the A.D. 1000s, in Chaco Canyon, one collection and diversion system could gather several hundred thousand gallons of runoff from a single cloudburst from the nearby cliffs and distribute the water to carefully constructed bordered fields through a system of ditches, head gates, and overflow ponds.

Capturing runoff can be risky, though. From the simple akchin field to field locations that catch over bank flooding from swollen rivers, farmers could lose their entire crop during a single large runoff. Therefore, farmers planted in a variety of locations and used diverse techniques. Many variations and innovations appeared over time. Some showed success and are still used today, while others seemed to have served only under particular conditions and in specific climatic regimes.

A simple but very labor-intensive farming innovation appeared after the great climate-induced migrations of the thirteenth century. To conserve soil moisture, farmers used gravel and cobbles as mulch on terrace-top fields. Rock-mulched fields are best known from the Chama River valley below Abiquiu, and they also found around the base and foothills of the Jemez Mountains and some outlying areas. Rock mulch is particularly effective at preventing evaporation, more so than even vegetal mulches. It takes three days for rock-mulched soils to lose the amount of water that non-mulched soils lose in one day, and an additional benefit is that the rocks also prevent erosion. Rock mulches are found in regions where snowfall amounts are modest and soil moisture levels at planting time are low. Perhaps the rock also catches blowing snow, increasing the water contributions from snow melt to the soil below. The appearance of the rock mulches also coincides with a time of cooler temperatures that lasted until the early sixteenth century. Since the rock absorbs solar radiation, the mulch may have provided some heating benefit during the early and late growing season. Despite the many seeming advantages of rock mulch, it is not reported as a common farming technique by early explorers or anthropologists. More than likely it worked best under specific climatic or soil conditions, so the rock-mulch method never became widespread or was dropped as climate changed.

Social adaptations to the recurrent or normal conditions of drought included the concrete and the abstract. Low population density and extensive social networks fostered flexible responses that effectively minimized the risk of catastrophe. Communities could disperse as households when necessary without jeopardizing the core social values that allowed the sense of community to be re-established once drought was past. Religious values and practices were portable and generally inclusive, allowing immigrants to a community to contribute complementary beliefs and rituals. Bad times were shared and suffered through by all, knowing that better conditions would be restored with combinations of patience, principles, and performance.

In the few cases where drought turned out to be the harbinger of serious climate change, social responses ranged from discomfort to mass migrations to spiritual revolution. Climatic crises in the late ninth and mid-eleventh centuries in the Four Corners were met initially with disruption of communities, probably famine, and definitely some violence. Yet, within only a few decades, adjustments in settlement, economy, and social structure were completed, and a new adaptation was in place.

The climate change in the thirteenth century was more extreme, ultimately causing the agricultural abandonment of the central Colorado Plateau. Disrupted lives and violent actions were common, and most chose long distance migration as a way out. Traditional and archaeological knowledge have since identified some communities of ancestral Hopi and Zuni people as far away as southern Arizona. In the face of these crises, old religious ideas were weakened, and within the next century the new climatic regime and its economy were greeted by a new mixture of religious ideology, including Katsina.

The final climatic crisis came on the threshold of Spanish colonization. The thirteenth-century climatic change was reversed in the late fifteenth century, weakening the stable economic and social adaptations developed over the preceding 200 to 250 years. And that wasn't all. Population movements by puebloan peoples, the spread of Navajo and Apachean peoples, incursions of bison-hunters from the plains, and the arrival of the Spanish (bringing both disease and domesticated animals) all coincided. Native peoples and colonists alike were struggling to accommodate a new environment, complicated by the new social setting of the Euroamerican era.

If you lived in the central Rio Grande Valley of New Mexico in the 1950s, you lived through the worst drought of the past 1,000 years (see sidebar). Yet in the northern Rio Grande Valley, that drought, though perceptible to residents, still provided above-average rainfall. Perhaps it is hard to imagine, but some of the droughts of the 1990s also have delivered more than average rainfall. As shown in the graph (accompanying the sidebar), people in the north central part of the state have enjoyed 200 years of higher than normal moisture. The droughts of the 1990s have not been sustained over several years, so it is unclear if any lessons have been learned. Except for a 150-year drought in the 1100s and 1200s, inhabitants of the northern Rio Grande Valley have luckily avoided many of the disastrous droughts that affected other New Mexicans. The wetter conditions likely served as a magnet for those who left northwestern New Mexico in the late 1200s. Note also that much of the state also suffered from drought through most of the 1500s, while its effects were more momentary in the upper Rio Grande Valley. Will those living north of Albuquerque continue to be so lucky? Unfortunately, there is no clear answer.

The question today is whether our recent droughts are a harbinger of change to come. Perhaps we are only experiencing those short fits of drought that have long occurred in the Southwest. If we are, however, facing a drier climate over the long term, then it is time that we take stock of the lessons of stability—and instability—of the past. The flexibility and cohesiveness of Native American societies over the past twenty centuries are remarkable, and their underlying values may be helpful to the future of contemporary communities. The solution to our drought—whether real or imagined, by comparison to the past—is complex. It isn't about just the water, although our current usage of more than 1,000 gallons-per-person per month is in sharp contrast to considerably less than 100 gallons per person per month in the past. Nor is it a simple revival of agricultural techniques that already were fading from memory by the 1930s and 1940s. It isn't even that there are so many more of us who find that living in a land of blue skies, purple mountains, intermittent vegetation, and *terra aridus* has become our lifeway, too. It is a sense of compromise, one that will support mobility, diversity, integration, and conservation in proportions that can be adjusted and maintained under the stress of scarcity. ■

How Dry Is It? Not as Dry as It Has Been

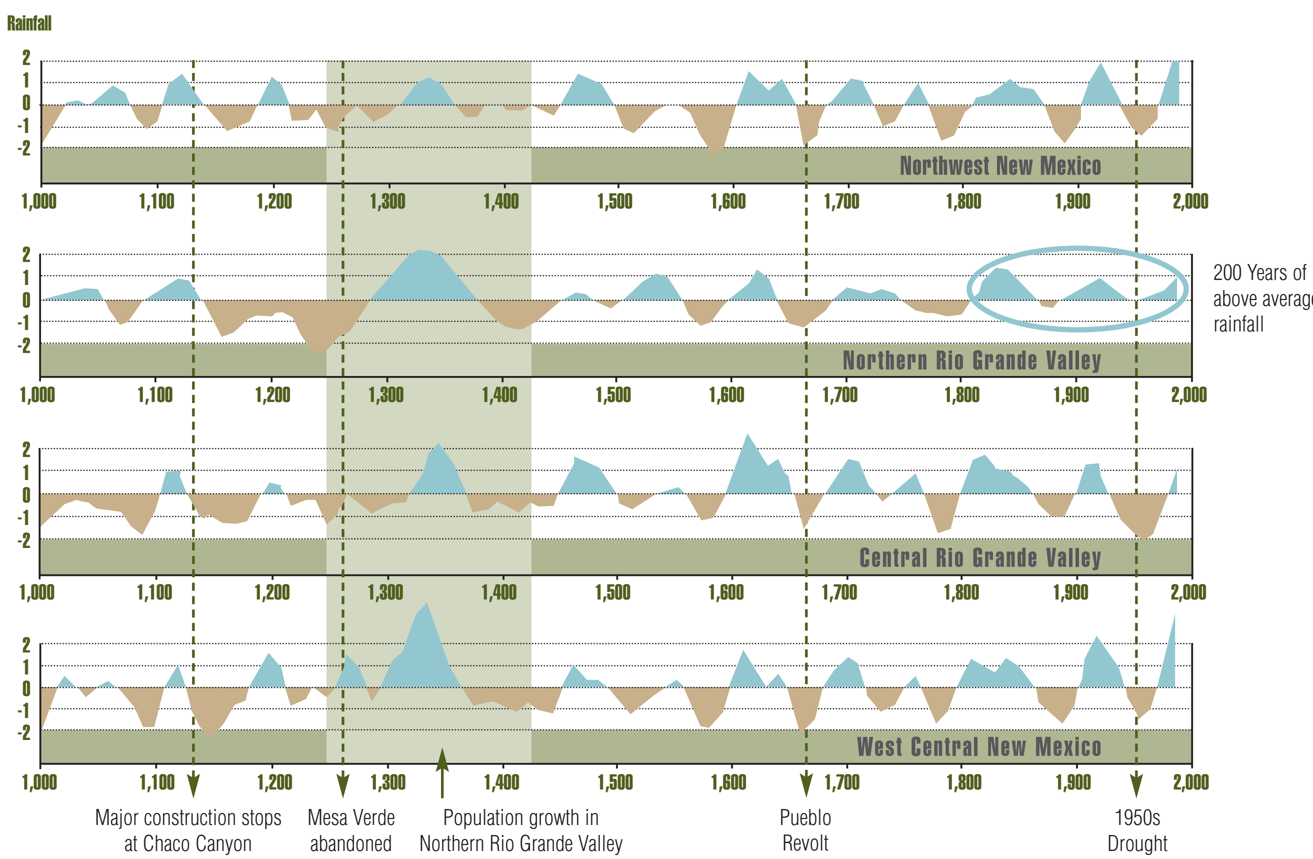
Based on thee-ring widths taken through 1988, these graphs show fluctuations in precipitation over the past 1,000 years. For comparison, each graph has a zero point that indicates the average amount of annual moisture in each region. The other numbers show how far an amount of annual rainfall departed from the average. The aqua represents above-average rainfall while the tan depicts dry periods. Shown are four geographical areas of New Mexico where ancestral pueblo people lived.

Though precipitation patterns are generally mirrored in each region, some important differences can be seen. While drought affected much of New Mexico in the mid- to late-1200s, the upper Rio Grande Valley recovered early and was wetter for a longer period than the other regions. This climate pattern may have helped attract populations from northwestern New Mexico who had experienced almost 150 years of dry conditions. It is during this period that population size began to grow in the northern Rio Grande Valley, eventually resulting in the establishment of the pueblos that we know today. The central Rio Grande Valley also witnessed the growth of many large pueblo communities as its generally wetter climate had fewer dry periods of great intensity or duration.

The Pueblo Revolt of 1680 was preceded by about twenty-five years of dry weather, which had an impact on both Native Americans and Spanish colonists. Tensions rose as both populations scrambled to cope with barely enough rainfall to grow crops. Drier conditions prevailed beyond the revolt, perhaps leading to continued factionalism among pueblo communities during the absence of the Spanish control.

The great drought of the 1950s affected every part of New Mexico to varying degrees. In the central Rio Grande Valley, it was the driest period of the past 1,000 years. In the upper Rio Grande region, rainfall decreased but was still above the 1,000-year average. People throughout the state were affected and older ranchers say that the only way to have made money on cattle was to sell their bones for fertilizer.

People living in the Rio Grande Valley north of Albuquerque have perhaps benefited the most from almost 200 years of above-average rainfall. Even during periods that were comparatively drier, more rainfall has arrived for a longer period of time than anywhere else in New Mexico, setting the record for the longest wet period of the past 1,000 years. —*Tim Maxwell and Eric Blinman*



This graph by Timothy D. Maxwell incorporates tree-ring data compiled by F. Ni, T. Cavazos, M. K. Hughes, A. C. Comrie, and G. Funkhouser (2002).