Planning and Drought

James C. Schwab, AICP, Editor

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Planning and Drought is the result of a partnership between the American Planning Association (APA), the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, and the National Integrated Drought Information System (NIDIS). Funding was provided by NIDIS's "Coping with Drought" initiative and the Sectoral Applications Research Program at the National Oceanic and Atmospheric Administration (NOAA), and the results of this work are dedicated to meeting public needs.

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CHAPTER 1

Drought: The Problem

By Jeff Brislawn, Marilyn Hall, AICP, Anna Ricklin, and James C. Schwab, AICP

Drought has not typically been a topic of concern among planners. In part, this may be due to a lack of clarity about what constitutes drought and therefore how it intersects with planning. Events such as tornadoes and hurricanes have distinct beginnings and ends demarcating bursts of meteorological activity that leave little doubt of when they are happening. When the earth starts to shake, we know an earthquake has begun. Beyond that, scientists largely focus on describing where an event falls along a spectrum of severity or probability.

Drought has typically been more ambiguous. Definitions of drought have varied, in part because it is a hazard event that lacks clear boundaries. *Drought-Ready Communities*, a planning guide developed by the National Drought Mitigation Center (NDMC), defines it as "a period of excessive dryness long or intense enough to affect agriculture, habitats, or people." At the same time, it says drought is "difficult to define because it often develops slowly over months or years, and has different impacts depending on the location, time of year, and sector of the community" (NDMC 2010, 4). The Congressional Research Service uses a similar definition while noting many others: "a lack of precipitation over an extended period, usually a season or more" (Folger, Cody, and Carter 2012, 1). More importantly, it notes that drought is "relative to some long-term average condition, or balance, between precipitation, evaporation, and transpiration by plants" (Folger, Cody, and Carter 2012, 4).

In short, while a tornado has the same characteristics wherever it occurs, the same is not necessarily true of drought. A level of rainfall that is perfectly normal in the desert may be a serious aberration in a more humid environment. Therefore, where drought occurs does matter, just in identifying the event as such. Combined with the slow onset of occurrence, these definitional problems have made drought more problematic than most hazards as an issue for planning to effectively address. Or so it has seemed.

In reality, drought is ultimately about the sufficiency of water, and communities have always depended on water for their economic and physical survival. To enhance their prospects, they have sought to control it, dam it, drill for it, and treat it on both the front and back ends of the user cycle. Life depends upon water. When nature fails to deliver expected quantities to a given area over an extended period of time, communities must make adjustments. How well they are prepared for those adjustments, or even recognize the need for them before it is too late, is a critical factor in determining the impact of drought. Those preparations provide a major opportunity for planning, and *Drought-Ready Communities* outlines both the nature and necessity of pursuing that opportunity. As recent droughts in Texas in 2011 and the Midwest in 2012 demonstrated, the stakes for affected communities can be distressingly high.

Consequently, this report begins by describing the impacts of drought on local and regional governments as a prelude to delineating what can be done—the nature of the opportunity for planners to make a meaningful difference. Those impacts extend well beyond a lack of water to the consequences of a lack of water: the decline of water quality; debilitation of public health in both mental and physical terms; damage to the natural environment; deterioration of public infrastructure and of some building foundations; economic losses; and a variety of potential secondary impacts from cascading hazards such as wildfires. Planners and their communities need to understand those potential impacts in order to identify the role of planning in addressing them.

WATER IMPACTS

Drought can affect surface water and groundwater supplies. The amount of surface water available to both human and natural systems diminishes as water levels are reduced in reservoirs, lakes, ponds, and wetlands. Streamflows decrease when springs dry up and soil moisture levels decline. Groundwater is also affected because aquifers are not recharged and can be depleted. When precipitation finally does come, surface water levels and streamflows decline quickly because the dry soil acts as a sponge, absorbing water that would otherwise remain on the surface in streams, ponds, lakes, and reservoirs. There are many hydrologic impacts of drought that go beyond the obvious water supply impacts. Drought affects water quality and can cause secondary impacts such as land subsidence.

Drought negatively affects water quality in several ways. The decreased volume of water in lakes, rivers, and other receiving bodies reduces their ability to absorb contaminants and increases the concentration of both point and nonpoint sources of pollution. Potential point sources of pollution include municipal sewer outfalls, industrial discharges, and thermoelectric power plant return flows. The discharges from point sources may need to be reduced to meet environmental standards if the concentration of contaminants becomes too high when water levels in receiving water bodies are low.

Nonpoint sources include stormwater runoff from urban areas, farms, and other places where the runoff may contain harmful pollutants and sediment. Drought can amplify the effects of stormwater pollution. Alternating events such as drought and heavy rain can negatively affect water quality, because organic materials and nutrients build up in the watershed and are then flushed downstream all at once. Furthermore, drought can increase wildfire potential, encourage invasive species, or increase forest mortality, resulting in short-term water quality problems and long-term watershed complications. For example, as plants die due to drought, runoff can more efficiently dislodge and transport sediment because of the increased soil erodability of damaged vegetative cover. More sedimentation in rivers can affect navigation and more sedimentation in water-supply reservoirs can reduce storage capacity and drought resiliency. The potential for high sediment yields resulting from drought demonstrates the need to consider landscape vulnerability in long-term planning and the importance of long-term monitoring for predicting water supply, navigation, and other impacts.

Drought-related degradation of water quality makes it harder to filter and decontaminate drinking water. As lake and reservoir levels decrease, algal growth can occur in warmer, stagnant waters; bottom sediments can become disturbed, clogging filters and interfering with disinfection; and previously immobilized contaminants can be released. Further exacerbating the situation, water-use conservation measures enforced during drought events can increase water age in a distribution system, leading to increased disinfectant by-products and reduced drinking-water quality (Wright et al. 2013).

Increased temperatures may accompany drought conditions, further degrading water quality. As air temperatures rise, water temperatures increase and the dissolved oxygen in water decreases, damaging aquatic habitat. Unusually warm winter temperatures, while not technically extreme weather, can result in earlier snowmelt, ice breakup, nutrient input, and subsequent algal growth in lakes and reservoirs. Most utilities are equipped to treat this water, but the ability to handle drought-related water quality and quantity issues diminishes as water infrastructure ages.

Low river flows are another water quality consequence of drought, which cause saltwater intrusion in tidally influenced sections of rivers. For example, during normal flows on the Mississippi River, freshwater pushes down and out of the mouth of the river. But with low flows during drought, the Gulf of Mexico will start to push saltwater up the Mississippi River. The saltwater from the Gulf of Mexico coming up the mouth of the Mississippi threatened industrial and municipal water intakes more than 60 miles inland during the drought of 2011–2013 (Elliot 2013).

Drought exacerbates land subsidence in many areas of the United States because large amounts of groundwater are withdrawn and not recharged at normal rates. When water is taken out of the soil, the soil collapses, compacts, and drops. This situation occurs throughout the United States, but has had more impact in California, Texas, Florida, and Arizona. As the ground collapses or shifts, it can damage infrastructure such as roads and water mains. Groundwater depletion can also cause sinkholes and damage infrastructure, homes, and other structures (USGS 2013).

PUBLIC HEALTH IMPACTS

Changes in water quality and the environmental impacts of drought can have serious consequences for human health. Particularly when drought is prolonged or accompanied by high heat conditions, the impacts on both mental and physical health can be significant. Therefore, it is critical that drought planning and drought response include consideration of the health and well-being of the public. Public health can be maintained and improved through planning, a systems approach, and the use of evidence-based practices (ASH n.d.).

The World Health Organization defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 1948). Every individual's health is shaped by a number of factors, including genetics, socioeconomic status, and behavior—all of which are expressed within the context of that person's physical environment. In Healthy People 2020, the U.S. Department of Health and Human Services (HHS) plan for addressing public health challenges throughout the United States, HHS identifies a number of physical environment features that impact human health. They include a number of features directly impacted by drought, including the natural environment (plants, weather, or climate change); homes, worksites, schools, and recreational settings; degree of exposure to toxic substances and other physical hazards; and aesthetic elements (trees and landscaping).

No one is immune from the impacts of drought, and when drought is severe, it can affect nearly all typical daily activities. Bathing, food preparation, sanitation, healthcare, recreation, and a host of other activities that contribute to health and well-being can be negatively impacted by drought. Such effects particularly burden vulnerable populations, such as young children, older adults, disabled persons, individuals with compromised health, and those living at or below the poverty line (U.S. HHS 2012).

Stress and Mental Health

The health impacts of drought can affect people living in cities, suburbs, or rural areas. The decreased air and water quality, particularly in combination with high temperatures, that results from drought can have direct negative impacts on health. However, the conditions and crises created by drought can also affect mental and physical health through a number of less direct pathways (CDC et al. 2010).

Because agriculture is one of the first sectors affected by drought, farmers and others working in agricultural jobs are particularly vulnerable to stress and worry during a drought. Stress can be caused by financial concerns and lack of productive work, and it can lead to serious depression, anxiety, alcohol abuse, and even suicide. These outcomes mainly occur among rural populations (CDC et al. 2010).

Other stressors can affect people living in cities and more populated areas. Water conservation rules and the lack of water available for usual daily activities can take a significant toll over time when combined with other taxing conditions, such as the urban heat island effect. These conditions can have a strong negative impact on mental health and psychological resilience of individuals, making them more susceptible to depression and anxiety, and reducing their ability to respond effectively to any additional stressors.

Sanitation and Hygiene

Water is critical to maintaining clean, sanitary conditions in all areas where people spend time, including homes, hospitals, workplaces, public spaces, and recreational facilities. With limited water supplies and potential restrictions on water use, people may conserve water even for basic hygienic needs and this could result in the spread of infectious diseases or the consumption of unclean foods (CDC et al. 2010).

Air and Water Quality

Ash from drought-related wildfires and dust from dry land can drastically reduce air quality, with higher concentrations of particulate matter in the air in areas affected by drought. Large pools of stagnant water can also lead to freshwater blooms of cyanobacteria, resulting in new airborne toxins. Poor air quality affects everyone, but people with chronic respiratory illnesses such as asthma and emphysema can have even more difficulty breathing and are at higher risk for infection under such conditions (CDC et al. 2010).

When water is scarce, the water that is available is often of lower quality and not ideal for consumption. Higher concentrations of toxic pollutants, salts, and other sediments in reservoirs can make it difficult to achieve the potable standards for water treated at municipal treatment facilities. Groundwater is similarly affected, thereby lowering water quality in areas where people rely on well water. Additional water testing is necessary to protect the population in these circumstances. In addition, stagnant water offers places for mosquitoes and other insects to thrive. These pests can then become vectors for the transmission of diseases such as West Nile virus (CDC et al. 2010).

Nutrition and Recreation

Insufficient rain and snow affect the production of food at multiple levels. With lower crop yields, food prices may rise or lead to shortages of both produce and meats. Additionally, in the face of water shortages, farmers may turn to unsafe sources of water for irrigation, resulting in the spread of infectious bacteria such as *Salmonella* and *E. coli* that can make their way to the consumer (CDC et al. 2010). Livestock affected by drought are at higher risk for disease and malnourishment. Freshwater sources of fish and shellfish are also at risk during a drought due to low water levels and higher concentrations of toxins. In both cases, infections and toxins can easily pass from these food sources to humans through consumption (CDC et al. 2010).

Lastly, although it may not be an immediate consideration when facing drought, lower water levels and decreased water quality make typical summer water sports unsafe. Waterborne diseases caused by bacteria, protozoa, or other toxins can make people sick, while lower water levels can put people at risk of injury. By extension, such impacts of drought could significantly affect local economies that rely on tourism and result in further stress and anxiety for small business owners (CDC et al. 2010).

ENVIRONMENTAL IMPACTS

In addition to the hydrological effects discussed earlier, many additional environmental impacts of drought affect natural systems (Table 1.1, p. 6). Aquatic ecosystems are put at risk when rivers, lakes, and groundwater levels are low and their ability to flush or assimilate pollutants is reduced. Salinity and saltwater intrusion issues arise in coastal areas, and terrestrial ecosystems are affected when habitat is lost or changed. In addition to the direct effects of diminished water quality and low water levels on ecosystems, many other environmental impacts are associated with drought. These

TABLE 1.1. ENVIRONMENTAL IMPACTS OF DROUGHT

Loss or destruction of fish and wildlife habitat
Lack of food and drinking water for wild animals
Increase in disease in wild animals because of reduced food, water supplies,and water quality
Increased competition and vulnerability to predation
Conflict with humans from migration and concentration of wildlife
Increased stress on endangered species
Loss of wetlands and estuaries
More intense wildfires
Wind and water erosion of soils, poor soil quality, and increased desertification
Weakened ecosystems more susceptible to invasive species, disease, and pests
Decreased air quality from dust and particulates
Degraded estuaries and riverine habitat caused by low river flows
Saltwater intrusion in tidally influenced sections of rivers
Loss of biodiversity
Decrease in landscape quality in urban areas from loss of trees and other vegetation

impacts vary by region and ecosystem, but every natural system is altered by drought in one way or another.

BUILT ENVIRONMENT IMPACTS

Drought can affect the built environment at different scales, from destroying the foundation of a building to damaging a significant portion of a city or region's infrastructure system. As with the many other consequences of drought, these impacts can be challenging to anticipate, identify, and mitigate.

Structures

Drought impacts to buildings are rarely mentioned because they are not as dramatic as the impacts from other hazards. However, several types of drought-related damages should be considered in drought planning. If a building is located on expansive soils, foundation cracking can occur as soil moisture decreases and clay-based soils contract. While this is a well-known relationship, no work has been done to directly relate drought and structural degradation (CWCB 2010a). Some recent examples of drought-induced structural damage occurred in Texas in 2011, including sagging foundations in areas of clay soils near Austin and more than 700 water-main breaks per day in Houston during the summer months (Llanos 2011). The near-record drought, combined with water restrictions that prevented homeowners from regularly soaking dry ground around homes to prevent soil from compressing, resulted in severely damaged home foundations. The costs for repairing such damage typically range from $15,000 to $20,000 but could be as much as $50,000 for a home with severe sagging and broken plumbing underneath the slab (Wear 2011). Homeowners insurance typically does not cover damage resulting from drought.

Buildings may be forced to change operations and maintenance procedures during drought. Landscaping could also be lost due to drought and locally imposed water restrictions. Though they are a secondary impact of drought, severe wildfires resulting from drought conditions can destroy buildings in their paths. This occurred in Colorado during droughts in 2002 and 2012. In addition to fire damage to buildings, smoke and ash in the air can harm heating, ventilating, and air conditioning (HVAC) systems in affected areas. Ash can also cause extra wear and tear on building exteriors.

Infrastructure

Damage to infrastructure can and often does occur from drought. This impact of drought is often overlooked, perhaps because the damage is usually sporadic and may become increasingly evident over time, as opposed to instantaneous damage from a flood or earthquake. Damage to underground pipelines and aboveground infrastructure can occur due to shrink-and-swell cycles associated with periods of drought when soils dry out and shrink and wet periods when soils expand. This is especially problematic in areas with high concentrations of clay in the soil.

Municipal Water Supply and Delivery. Drought was a major problem for infrastructure in Texas during 2011, causing damage to foundations, roads, pipes, and underground water and sewer lines. The City of Austin repaired 103 leaking pipes in the last week of July alone. Fort Worth reported more than 200 breaks in its water mains in July, including 20 discovered on a single day (Auber 2011). Houston had over 1,000 active leaks in its water system by the end of August 2011 (Combs 2011). Water-main breaks occurring during the height of drought, when conserving every drop of water becomes important, have compounding consequences.

Drought can also directly affect water storage and distribution systems. Decreased pore water pressure from low water levels can increase the potential for structural damage to earthen dams. As reservoir water levels decline, shoreline areas are exposed and susceptible to erosion, leading to increased sedimentation. Damage to water distribution and treatment systems can be caused by high sediment loads when pulling water from the bottom of low reservoirs. In severe cases this can cause damage to outlet structures and water treatment facilities. In general, increased maintenance and oversight are required for these structures during drought. Increased silting and sedimentation in reservoirs as a result of drought and fire-damaged watersheds can ultimately require expensive dredging operations. Water-supply ditches that remain dry for extended periods of time can be prone to animal damage such as burrowing and plant overgrowth.

Municipal Wastewater. While water treatment systems see an increase in demand during drought, wastewater systems can experience the opposite: decreased flow. This can cause challenges both at the plant and in the collection system. Because wastewater most often flows by gravity from the point of origin to the plant, decreased flows travel more slowly than usual, allowing solids such as plastics, rags, and strings to fall to the bottom of pipes and accumulate at pipe joints and in junction boxes. Although wastewater plants treat less water during a drought, the influent is stronger, with greater concentrations of ammonia and total suspended solids, which can cause issues if not properly managed. Wastewater effluents are often discharged to waterways and used again downstream as water supplies. A decrease in effluent quality, especially with less stream water for dilution at low flow, could adversely affect the quality of water remaining for future use.

Transportation. Recent examples of drought impacts on roads include those in Williamson County, Texas, near Austin in the summer of 2011. The county had around 100 road and bridge employees working full-time to fix pavement cracks (Wear 2011). The most common type of impact was longitudinal cracking with breaks in the asphalt parallel to the road's center stripe. The cracks typically started near the road's outer edge because the soil alongside the pavement was exposed to the heat and lost moisture to evaporation. As the soil began to compress, it would bend the outside of the road. A series of three or four cracks were often observed as the drying progressed toward the road's center. The drought also caused problems with concrete box culverts running crossways underneath roads. The culverts tended to remain stationary, but the asphalt on either side sagged from soil displacement and cracks formed across the road.

While not always associated with drought, intense heat can cause the surface of roads to deform as pavement expands in the heat. The pavement pushes up off the ground at its weak spots when there is no place for it to expand, or where cracks have weakened the pavement, particularly in areas of poor drainage. The risk for roads buckling is greatest when the temperature is over 90 degrees for extended periods. The result can have public safety consequences. Hot weather in Wisconsin in 2012 caused a motorist to become airborne when a highway buckled under the heat and formed a ramp. The Wisconsin Department of Transportation reported 17 pavement buckles on major highways on July 4, 2012 ("Record Heat Buckles Pavement" 2012).

Droughts can cause another secondary impact related to erosion. During construction, road crews typically put up silt fences to stop runoff of soil churned up by heavy equipment. As soon as is practical, workers plant grass in those disturbed areas to prevent erosion. Planting may prove difficult or not make sense during a drought, making the area susceptible to erosion from wind and the occasional rain.

Energy. Power plants require large amounts of water for cooling purposes. While droughts rarely get to the point of causing blackouts or brownouts, extended droughts can affect the price and availability of electrical power. In western states, many power providers purchase senior water rights to ensure reliable supplies during drought conditions. However, a senior water right does not always guarantee water in extremely dry conditions. During multiyear droughts, relatively senior water rights could be without priority and consequently a provider would not have sufficient supplies. The energy and power sector in Wyoming has been affected by drought; in 2008, the Laramie River Station power plant in Wheatland faced the risk of running out of cooling water due to drought conditions. The power plant had to draw water from the High Plains Aquifer and the Wheatland Irrigation District to meet its cooling water demand.

Drought and dust storms can cause problems for power line infrastructure. When dust and other contaminants coat insulators on power lines and get damp, they can conduct electricity and cause failures resulting in blackouts. Wildfires associated with drought also can also damage power line infrastructure.

Hydropower plants, by their very nature, are susceptible to drought. During periods of drought, streams carry less water; hydroelectric plants therefore cannot produce as much electricity and may need to go off-line entirely depending on the severity of conditions and possibly the seniority of their water rights. Less hydropower means that the difference must be made up by energy from other sources, which can be more expensive and result in price increases for consumers. Droughts may slow or increase the cost of energy development as the nation's oil industry becomes increasingly dependent on hydraulic fracturing which, by definition, relies on water.

City Parks, Landscaping, and Public Facilities. A city or town's green infrastructure can also be impacted by drought. This includes sports fields, parks, golf courses, and related facilities that need water, such as outdoor drinking fountains, swimming pools, and ornamental fountains. In 2011 the City of Dallas closed more than two dozen athletic fields due to cracks in the soil up to two feet deep (Drago 2011). The City of Denver closed access to its soccer fields in February 2013 because of drought conditions and concerns over extended turf damage prior to spring green-up. In addition, drought can take its toll on publicly owned landscaping and urban forests.

SECONDARY HAZARDS

Besides having many direct impacts on communities, drought may also exacerbate other hazards. Wildfires need three ingredients to sustain them: oxygen, fuel, and heat. Oxygen is supplied naturally by the atmosphere, and certain firefighting techniques aim to deprive fires of oxygen by smothering them. Fuel availability is a consequence of forest and grassland growth, but its effect is dampened by moisture. Because a wet forest burns more slowly than a dry one, weather conditions have a huge impact on vulnerability to wildfires. Under wetter conditions, more heat is needed to overcome the fire-retardant qualities of water. Thus, though drought does not necessarily lead to increased risk of wildfires, it can foster such conditions when accompanied by high temperatures that speed evaporation and turn previously healthy forest or grassland into dry kindling. Such threats are known as secondary hazards, the result of cascading impacts in which one hazard produces conditions that lead to one or more other hazards. For instance, intense rainstorms have been known to induce landslides, as the increased weight and reduced friction of the vulnerable slope yields to the pressure of gravity.

Wildfires in both Texas in 2011 and Colorado in 2012 reflect these dangers. Severe drought in Texas had baked much of the state for months and coincided with the hottest summer on record. As of October 4, 2011, 97 percent of Texas has been in extreme or exceptional drought conditions (Stepney 2012). The combination of low moisture and heat produced a cauldron in which wildfires could tear through a state already short on the water needed to fight such fires. As a result, Texas in 2011 saw 3,120 resource orders mobilized for firefighting, more than any other state except California and nearly three times as many as the state with the third-highest number, Arizona. The massive fire damages added to the estimated $5.2 billion toll imposed by the drought. To say that this scenario imposed enormous strains on the Texas emergency management system is to state the case mildly. Ultimately, 22,790 fires consumed over 3.7 million acres and destroyed more than 2,700 homes (InciWeb 2011).

Just a year later, similar scenes played out on a somewhat smaller scale in Colorado, at least partly as a result of ongoing patterns of drought and high heat. The most damaging—the Waldo Canyon Fire—beset Colorado Springs in June 2012, killing two and destroying almost 350 homes (Huffington Post 2013). These two examples alone should be sufficient for most jurisdictions subject to such conditions to consider wildfires an ancillary hazard to drought in their hazard mitigation plans.

Although wildfires are clearly the most drastic and dramatic secondary hazards associated with drought, some others are worth considering, including subsidence due to low groundwater levels. In addition, when rain does finally come, exceedingly dry land may have become too hard to absorb runoff easily, thus causing soil erosion and even some flooding due to resulting sediment loads in streams and rivers.

ECONOMIC IMPACTS

The economy derives many benefits from water. When water is "in-stream," we rely on flows for hydropower production, once-through electric power plant cooling, navigation, recreation, and healthy ecosystems. "Off-stream" benefits come from withdrawing water from streams, rivers, lakes, and aquifers. This water is used for municipal, industrial, agricultural, and power plant–cooling uses.

Water is integral to the production of goods and services. The economic impacts of drought affect many sectors of the economy and reach well beyond the area experiencing physical drought. Direct economic impacts of drought affect industries including agriculture, recreation, energy, tourism, timber, fisheries, and others that rely heavily on water. Indirect economic impacts of drought can be just as severe and damaging as direct impacts. Indirect impacts include job losses, business failures, lost investments, economic uncertainty, and changed development and consumption patterns.

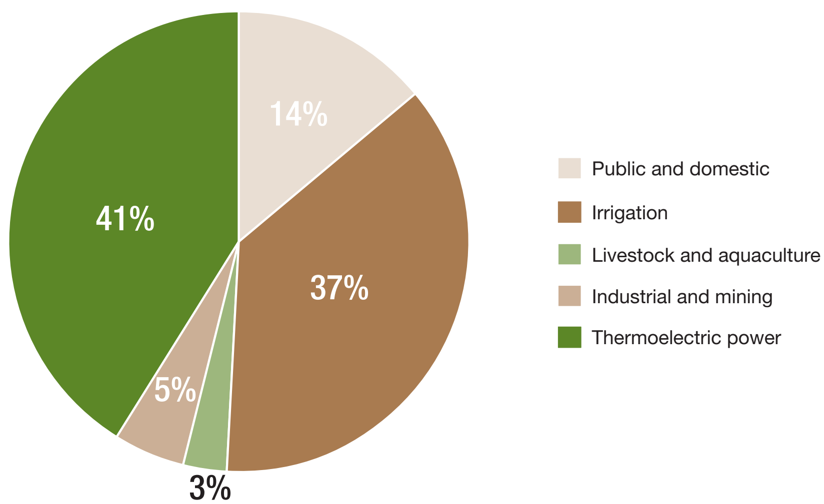

Figure 1.1. *U.S. freshwater withdrawals, 2005*

Source: Kenny et al. 2009

The economic impacts of drought vary by region. It is important to understand how water is used by each sector in a region to identify potential drought impacts. In 2005 irrigation and electric power plant cooling accounted for approximately 78 percent of total freshwater withdrawals in the United States. Municipal and industrial withdrawals accounted for 19 percent, and livestock and aquaculture for 3 percent (Kenny et al. 2009). Figure 1.1 shows the breakdown of freshwater water withdrawals in the U.S.

Consumptive use is an important issue when evaluating the impact of water withdrawals on water supplies. Consumptive use of water occurs when water is withdrawn from a water source and not returned to the source. Most thermoelectric withdrawals are returned to the water source after cooling, while most irrigation withdrawals are used up by the processes of evapotranspiration and plant growth.

Comparing freshwater use in 2005 from withdrawals in New York State and California illustrates the need to examine a region's water use to understand the ways in which a drought may affect the economy. The Southwest, including California, produces more than half of the country's "high-value specialty" crops, those with intensive management and irrigation needs (Banerjee 2013). Figure 1.2 shows that nearly three-fourths of all water withdrawals in California were used for irrigation. This water consumption depletes the water available for other uses. Drought and increased competition for water between sectors can cripple California's agricultural communities, which are vital to the state's entire economy.

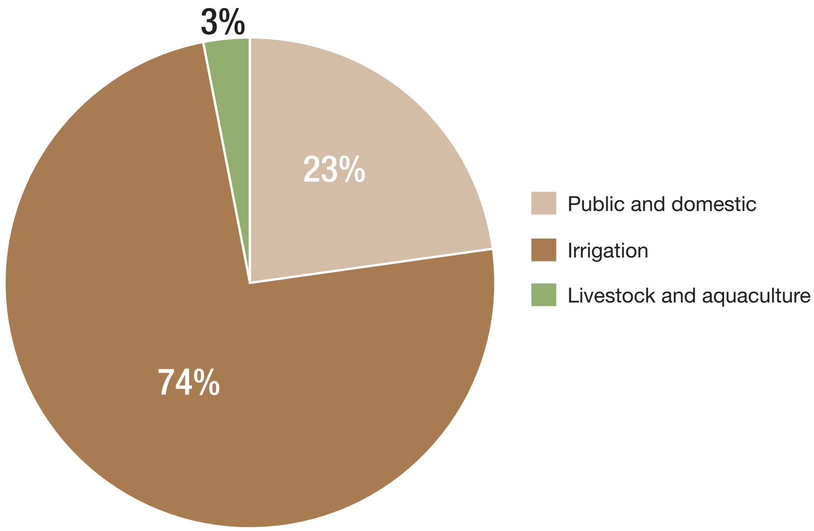

Figure 1.2. *California freshwater withdrawals, 2005*

Source: Kenny et al. 2009

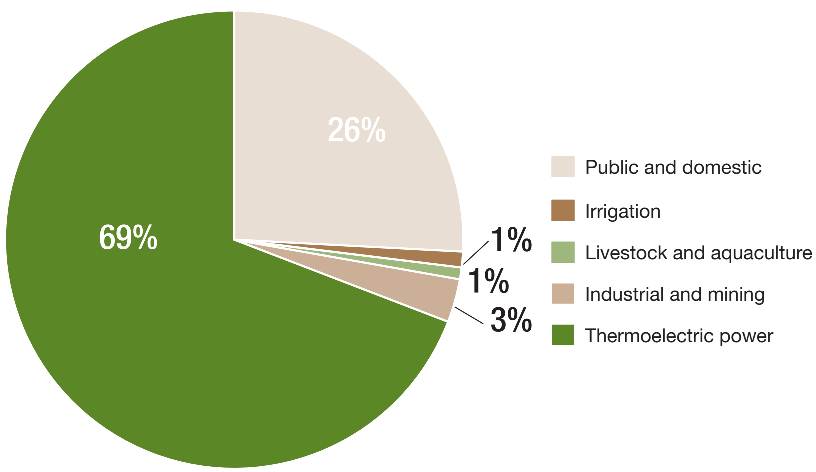

Figure 1.3. *New York freshwater withdrawals, 2005*

Source: Kenny et al. 2009

At the same time, California used less than 1 percent of water withdrawals for thermoelectric power. It relies less on thermoelectric power than other states, and most of the thermoelectric plants in the state utilize saline water for cooling instead of freshwater. In 2010, 47 percent of California's electricity was generated using natural gas. Natural gas plants use much less water than thermoelectric steam generation units. Drought still impacts electricity production in California, however, because hydroelectric power accounts for about 16 percent of electricity generated in the state (U.S. EIA 2012). The need for water for hydroelectric plants is not included in the withdrawals chart shown above. Decreasing snow packs, river flows, and reservoir levels reduce hydroelectric power availability.

In New York, thermoelectric power was the predominant use of freshwater, accounting for 69 percent of water withdrawals (Figure 1.3). Compared to California, New York's electricity generation was much more dependent on freshwater withdrawals. New York's use of nuclear, coal, and hydroelectric power also makes its electrical grid more susceptible to drought-related disruptions than California's. Although it relies heavily on freshwater withdrawals, New York has increased its resiliency to drought by decreasing its dependency on thermoelectric power. In 2000, 28 percent of its electricity was from coal and petroleum power plants; by 2010, that had declined to about 10 percent (U.S. EIA 2012).

About a quarter of freshwater withdrawals in both California and New York go to public and domestic users. This water is distributed to homes and businesses through local water providers. Conservation efforts can reduce demand in this sector, but in California the largest impact will come from conservation and efficiency efforts in irrigation. Since thermoelectric power is the predominant use in New York and it is considerably less consumptive than domestic and public use, conserving electricity will have the greatest effect on increasing or improving water availability in New York.

Direct Economic Impacts

Many of the direct economic impacts occur in agriculture and related sectors. These sectors rely on precipitation and surface and groundwater supplies. The widespread drought experienced in 2011 and 2012 caused a dramatic deterioration of grass and grain crops across the U.S. that shocked the country's agricultural community. The drought led to deteriorating pasture conditions that forced more young cattle into feedlots and caused more beef cows than expected to be culled, resulting in turmoil throughout the agriculture industry (Kay 2012). In addition to losses in yields of crop and livestock production, drought is associated with insect infestations, plant disease, and wind erosion. Drilling new wells, paying for more expensive livestock feed, and spending more on irrigation increases the cost of farming during a drought. A related sector equally impacted by drought is the timber industry, as weakened trees are at higher risk for disease, pest infestation, and fires.

The "green industry"—landscapers, irrigation companies, growers of landscaping plants, and the businesses that sell plants—can be particularly weakened by drought, as these specialized industries and their customers are especially dependent on steady water supplies. When a community must impose outdoor watering restrictions and when the cost of water increases as a result of water shortages, small specialized nurseries become vulnerable as demand for their products declines. Large home-improvement retailers such as Lowe's and Home Depot are similarly affected. As a result of the 2011–2012 drought, Lowe's reported weaker sales than expected in mid-Atlantic, southeastern, and western regions of the U.S. (AP 2007).

Recreation and tourism are directly affected by drought as well. Hunting, fishing, water skiing, and other outdoor activities are dependent on healthy ecosystems and adequate water levels in streams, lakes, and reservoirs. Additionally, local economies that depend on winter sports such as skiing and snowmobiling can be devastated by droughts that reduce snowfall.

Indirect Economic Impacts

Increased costs and shortages create a ripple effect throughout the economy. Drought creates a loss of income for affected sectors, which drives many of the secondary impacts of drought. Income loss in the agricultural sector provides a good example. Retailers and others who provide goods and services to farmers also see a reduction in income because farmers have less money to spend. This leads to unemployment, increased credit risk for financial institutions, capital shortfalls, and eventual loss of tax revenue for local, state, and federal governments.

In addition to widespread losses of income, secondary effects of drought can be seen in price increases throughout the economy driven by shortages of products affected by drought. Prices for food, energy, and other commodities increase as supplies are reduced. A clear example is when drought reduces corn yields and prices rise. The increased price of corn stresses livestock suppliers. Higher feed prices and shortages can cause the liquidation of breeding livestock, causing short-term increases in beef, pork, and poultry supply and reducing short-term prices. However, over time this reduces supply and increases prices as breeding stock is sold off (Kay 2012). Higher corn prices also add to controversy and debate over using corn for ethanol versus for food and livestock feed (Tokgoz et al. 2008).

Navigation of shipping channels such as the Mississippi River can be dramatically influenced by drought. Reduced flows in rivers impair navigability and result in increased transportation costs because products must be transported by alternative means. In some cases, local shortages of certain goods lead to the importing of these goods from outside the drought-stricken region. Increasing transportation distance coupled with increased transportation costs compound the impacts of drought on commodity prices (Schwartz 2013).

Drought affects both water availability and demand, leading to greater competition among uses and users. Droughts are often accompanied by warm temperatures that lead to increased demand by water and electric utility customers. Often, when the demand for water is the highest, supplies are the lowest. The demand is highest in the summer when people are irrigating their lawns, growing gardens, cranking up cooling towers, and playing in sprinklers. Late summer is also the time of year when river levels naturally are their lowest. Increased human demand combined with natural summer pressures can intensify water shortages. This is also true for electricity. When the weather gets hot, the demand for air conditioning increases. This occurs at a time when water availability is at its lowest. As we have seen above, water and electricity are inextricably linked.

The impacts of water shortages are hastening efficiency improvements in water use. At the national level in the United States, total freshwater withdrawals have leveled off since 1980, despite the addition of more than 68 million people to the population. Per capita water use is considerably less than it was in the 1980s because of increases in irrigation efficiency for agriculture, more efficient cooling processes in electrical generation, improved efficiency of water-using fixtures and appliances, and reductions in exterior landscape watering. Many of the efficiency gains that result from drought become permanent. Examples include the replacement of inefficient water fixtures in the residential sector and the replacement of older once-through cooling systems by systems that recycle cooling water in the industrial sector. This demand reduction becomes permanent and improves resiliency during times of drought. However, as water efficiency increases, demand hardens, and it becomes more difficult to reduce water use during water shortages.

The increases in efficiency and the resulting trend toward less demand for water lead to increases in the per-unit cost of water. Utilities must continue to maintain infrastructure such as water treatment plants and water distribution systems regardless of how much water is sold. Also, the cost of providing water increases as water utilities invest in new water supplies and purification technologies. Thus, the per-unit cost of water must increase to meet the fixed costs of running the utilities. This is also true for electricity providers: when water is scarce, power companies that normally rely on hydroelectric or thermoelectric power must find other fuel sources.

DROUGHT AS A CHALLENGE FOR PLANNERS

The overall intent of this chapter has been to introduce planners and other readers of this report to the range of documented impacts that accompany drought. Understanding such impacts is paramount in making the case for establishing drought as a priority in local planning. However, impacts alone do not empower a community to take action. For planning to be effective, the community must be persuaded that specific actions can be taken to address the problem. Otherwise, problems with no clear means of resolution are merely a rationale for helplessness and inaction.

What can planners and their communities do about drought? The starting point for any discussion on this topic is whether planning has anything to do with water consumption. There are two sides to the drought equation: water supply, which is in most cases ultimately a result of precipitation, and water consumption, which results from human uses of water and the nature of our built environment. The impacts of drought result from the combination of imbalances between these two and not just from prolonged reductions in rainfall. Planning cannot influence rainfall, but it definitely has much to do with consumption patterns, both over the long term and within a period of drought.

One example of such an impact, whether intended or not, stems from patterns of urban development in communities. Large lots tend to encourage a significant amount of summertime lawn watering. More compact residential development does not eliminate water use for lawns, but reduces it considerably. Another is the role of building codes, which can influence the use of water-conserving devices, though only prospectively because new code requirements generally do not apply to existing buildings. Landscaping codes can also influence water use, particularly in areas where water-consumptive vegetation is inappropriate for the local climate. Coincidentally, landscaping codes have been used to mitigate wildfire risk (Schwab and Meck 2005). All of these potential reductions of the impacts of drought can be addressed in comprehensive plans and in the codes and ordinances that implement the goals of local plans, as well as through procedures such as subdivision, planned unit development, and site plan approvals. The resulting overall reductions in water use can help create a more resilient institutional environment within which specific measures responding to drought can more readily succeed.

Chapter 3 will deal more directly with the tools planners have at their disposal for addressing drought as a periodic natural hazard, as well as who should be involved, how to effectively communicate about drought issues, and the types of plans through which a community can develop appropriate policies. But first, the next chapter establishes both what we know scientifically about drought—the knowledge base that is available to planners—and how we know it. Chapter 2 will also introduce readers to the toolboxes and resources for drought issues available to planners. As with any other natural hazard, planners need to know where to find the best repositories of information from expert sources.

CHAPTER 2

Drought: The Knowledge Base

Cody Knutson, Kelly Redmond, and Mark Svoboda

Drought is an irregular and recurrent natural feature of climate. For the purposes of this discussion, drought represents an accumulated deficit in the water budget of some system of interest, leading to one or more impacts on that system. Such impacts are usually viewed and labeled as negative, but can be positive from other perspectives; indeed, some natural systems have evolved to obtain advantage from sporadic dry conditions. Such systems may be hydrological, agricultural, biological, ecological, or economic. Impacts from a given sequence of atmospheric events can vary, sometimes substantially, among different sectors, depending on sequencing and timing, prior climate history, and the existing condition of the system of interest.

A water budget consists of terms that increase water (e.g., precipitation and snow melt) and that decrease water (e.g., evaporation and transpiration). Drought is present when prolonged differences between supply rates and demand rates cause repositories of water (reservoirs, streams, groundwater, organisms, plant cells) to fall below thresholds that then lead to impacts. Because both supply and demand are involved, drought is not simply a matter of reduced precipitation; it is also determined by other factors that affect water loss, including temperature, wind, humidity, and solar radiation.

In most climates there exists at least one—sometimes two, occasionally three—dominant seasons of precipitation supply, and the worst droughts typically are a result of the loss of one or more of these wet seasons. In regions with a single annual peak in precipitation, for example, no opportunities for replenishment can occur until the same time a year later. Climates with more uniform monthly precipitation or secondary peaks have more opportunity for speedier recovery.

The annual cycle of precipitation varies greatly from region to region, and in mountains both amount and seasonality typically vary by local elevation (at higher elevations, a higher fraction comes in winter). Plants have evolved different strategies of growth over the annual cycle and are often very susceptible to adverse environmental conditions at critical points in the year. For these reasons, drought manifests itself in many different ways—a dozen or two across the U.S. alone.

A widely held view is that there is usually some correspondence between duration and spatial extent of drought (i.e., lengthy droughts cover large areas). There are hints, however, from contemporary and paleoclimate records that this may not always be necessarily true, and the question remains open for debate about whether droughts lasting two or more years (on to decades or centuries) can occur in small areas.

SPATIAL AND SEASONAL PATTERNS OF DROUGHT

Droughts can occur anywhere in any climate. By definition they represent a prolonged and unusual departure from the average level of precipitation for that particular climate. The classic image is cracked soil in the bed of a stock pond under the shimmering sun in the American heartland. Drought, however, is defined in terms of some reference climate, and droughts in very wet or very dry climates, or in cold or hot regions, express themselves differently and may be harder to detect.

We know from paleoclimate reconstructions (tree rings, sediments, etc.) that past droughts have in some parts of the U.S. lasted 20 to 50 years or more. Around the globe and across North America we commonly see more than one area in drought at a given time. The atmosphere can become established in persistent modes of circulation that allow storm tracks and moisture replenishment to favor some locations and neglect others. Nationwide, measurable precipitation occurs about once every three days averaged across the United States, varying from 2 out of 3 days (winter, Pacific Northwest) to 1 out of 14 days (desert Southwest).

Climatologists are moving towards a greater appreciation of the role of the biosphere, as plants both affect and are affected by climate. For example, moisture in the air moving north from the Gulf of Mexico in summer over the Great Plains is augmented by that from local evaporation from grasses, grains, leafy agriculture, and natural vegetation. These help fuel the summer afternoon rainstorms that agriculture in that area has come to rely on. When summer storms diminish and produce less rain, less moisture subsequently evaporates to fuel the next day's storms. This feedback loop reinforces the initial tendency toward less precipitation. Summer drought in the southern Great Plains typically leads to a drier atmosphere, less conducive to rain in the central and northern Great Plains, as well as fewer clouds, more sunlight, less transpiration from plants, and greater drying of soil.

Drought conditions can establish fairly quickly in summer, when moisture loss rates due to evaporation from soil and transpiration from leaf surfaces of plants are already high. Precipitation occurs irregularly, but this quiet and invisible process of evapotranspiration occurs steadily with few interruptions. Evaporation occurs faster at higher temperatures, higher wind speeds, higher solar radiation, and lower humidity. For plants to remain healthy, they must have access to enough water to meet demand. Plant life stages are keenly tuned to the annual cycle, and they often have critical windows of one to three weeks where favorable moisture conditions are needed for continued survival.

Conditions from the previous summer, autumn, or winter set the stage for the year's spring growth through the amount of moisture in the soil. The relative timing and sequencing of temperature and precipitation episodes can make a difference. In late autumn or winter, cold waves before precipitation episodes can freeze the soil; spring snowmelt and rain cannot penetrate the top layer of soil and instead run off. Liquid precipitation before cold waves, however, can wet the soil before it freezes. Snow before severe cold waves can insulate the underlying soil and reduce or prevent freezing. This then allows the snow to melt into the soil in the spring. Today's drought intensity is in part determined by months of previous conditions, at times extending over the past year or more.

In different parts of the United States, both human and ecological systems vary considerably in their vulnerability to drought. East of longitude 95° west, which falls roughly along the Missouri/Kansas border, precipitation tends to be uniformly distributed during the year, with most monthly averages departing no more than a quarter to a third from the annual monthly average. There is much more variation in precipitation seasonality in the West than the East. Over most of the eastern part of the U.S, 40 to 60 percent of annual precipitation returns to the atmosphere through evapotranspiration rather than flowing into a river or an aquifer (Sanford and Selnick 2013), decreasing to about a third in northern New England. West of longitude 95° west, this rises to between 70 and 100 percent just east of the Rocky Mountains. In the 11 westernmost continental states, levels of evapotranspiration vary: 10 to 30 percent of annual precipitation along the north Pacific Coast, 30 to 60 percent in northern mountains, and 70 to 100 percent in the West's southern half. In some parts of the Southwest, all the rain that falls becomes water vapor rather than surface or ground water.

In addition, the mechanisms for delivery of precipitation change with the seasons.

Winter

Though meteorologists often consider "winter" to be December through February, winter (or "cool season") can encompass three to seven months depending on sector and location. Accumulated snowfall melts in spring to furnish the summer's water, a process vital to the mountainous western states. Depending on elevation, the snow season begins as early as October, with peak accumulation ranging from about late February in the southern Rockies to early or mid-May in the highest elevations of the northern Rockies, with final melt-out occurring in May, June, or July. Here, winter precipitation is driven by large-scale cyclonic storms arriving from the Pacific and moving eastward. In the Cascades and northern Sierra Nevada, about 20 to 25 storms bring most of this moisture; in the southern Sierra Nevada and Colorado Plateau, a significant portion of the total winter precipitation arrives in just three to five major storms. Along the West Coast, if not enough storms arrive and precipitation is insufficient between November and April, the next realistic opportunity for recovery will not be until the following winter and spring.

Across much of the West, winter precipitation is important for the summer growth of forests. A dry winter greatly favors pathogens, insect pests, and fire, and often the effects of such deficits cannot be overcome by spring or summer precipitation. In the Northeast U.S. and upper Midwest, winter precipitation that melts around March or April is an important component of the annual hydrological budget. Across the northern Great Plains, a modest winter snowpack will insulate the soil and protect native and agriculturally important crops (e.g., winter wheat) against freeze damage. By contrast, in peninsular Florida, winter is the main dry season. Snow is widely considered in the West to be a frozen "free" reservoir provided by nature. For safety purposes, reservoirs designed to catch snowmelt must be held below predetermined levels to intercept runoff from warm storms that bring rain to unusually high elevations. All water above these levels must be passed through to remain below the safety threshold.

Spring

As the sun arcs higher across the sky, snow begins to melt, and vegetation begins to draw water. In some parts of the country, such as the northwestern upper Great Plains, April through June is the period of peak precipitation and a "second chance" to make up for winter deficits. Spring precipitation is generally cool and thus more readily makes its way into the soil column. Spring temperature provides an important control on whether winter and spring moisture moves into the soil at a controlled rate, or is lost to the atmosphere through evaporation and spring windstorms. This period can bring extended cool spells reminiscent of the fading winter, or heat spells that anticipate summer. In the southern Great Plains, agricultural growth is well under way and in some circumstances is at peak rates. Depending on the geographic context, those needing irrigation water during late spring and through the summer are usually securing financial assistance at this time. In the Southwest, precipitation events become more rare as this season progresses, with very little after April.

Summer

This is the season of highest absolute temperatures and of greatest evapotranspiration. In the Great Plains this is also the wettest portion of the year. In some western and southern parts of the High Plains, late spring and early summer are the wettest months. During this time many grasses and cereal crops begin to cure and turn brown. Winter wheat harvest begins by early June in southern Texas and starts later northward to early August in North Dakota and Montana. Although drought is generally a slow onset phenomenon, dry weather for one to three weeks can make a large difference in crop value during ripening.

Most summer precipitation in the West is driven by the North American monsoon system, which moves northward out of Mexico from the Gulf of California around early July. The Four Corners states are most affected, with moist air entering Arizona and New Mexico from the south and then curving east to Utah, Colorado, and sometimes Wyoming. This is a significant precipitation season for the Southwest, but mostly of benefit to vegetation; very little hydrologic recharge can occur because of the high temperatures and water loss rates. Locations in a broad arc to the west, north, and east of the monsoon-affected area often experience a decrease in precipitation from July onward. Reservoirs are steadily drawn down as needed, with some opportunity for recharge in the East and little opportunity in the West. Tropical storms begin to form and can bring significant precipitation to locations mostly in the southeastern quarter of the U.S.

Autumn

Most harvest has taken place, evaporative demand is on the wane, and streams and reservoirs generally reach their lowest point sometime in September or October. The annual replenishment cycle begins anew in the mountain states, as reservoirs are drawn down to legally mandated levels in anticipation of winter floods. A few landfalling tropical storms typically bring heavy precipitation to parts of the Southeast; the more numerous tropical storms in the eastern Pacific do also occasionally send moisture plumes to the Southwest. Along the northern West Coast the winter precipitation season begins ramping up during October as the storm track starts to shift southward from the latitude of British Columbia. By the start of November, the winter pattern is typically firmly in place in Washington and Oregon. Across the western states, warm storms can help recharge the soil water profile in the mountains before the first snow begins to stick. Autumn helps determine the extent to which carry-over effects of dry antecedent periods will affect drought status the following spring and summer.

DROUGHT AND CLIMATE CHANGES

Climate is characterized by fluctuations on scales that vary from fast (weeks, months, or a few years) to slow (years, decades, or centuries). It responds as a physical system to any change in the flow of energy in its constituent parts—and human activities cause changes in these energy flows. By-products of the metabolism of civilization, such as greenhouse gases and aerosols as well as land-surface alterations, are having effects on global and regional climate that are now being seen in observational records.

Although global precipitation is expected to increase somewhat due to climate change, the main effects anticipated will be a redistribution of where and when precipitation falls. During the next half century, the more northerly latitudes in the U.S. should see a modest increase in precipitation of about 5 to 10 percent from levels of the late twentieth century, and the more southerly latitudes near the Mexico border should see a decrease of a similar amount. For water management and drought, changes in seasonal distribution of precipitation may be more consequential than changes in the annual total. Winter precipitation is expected to increase in much of the nation, including the West, except near the Mexico border. In the West, spring, summer, and autumn are expected to see a modest precipitation reduction.

Precipitation certainly matters, but the role of temperature in drought cannot be neglected. Higher temperatures have the same effect as reduced precipitation, through increased evapotranspiration, and over a more extended season. The general implication of increased warmth is a greater frequency of more drought-like conditions. Though winters may be wetter with more intense precipitation episodes, the remainder of the year may be drier, meaning that winter floods and summer drought may both increase, especially in the West. The lack of heavy winter storms during such a shortened season may be a source of drought in some years. With more rain and higher elevation snowpack, the delayed but beneficial effects of snow may diminish. Added reservoir storage is not viewed as a widely viable solution, as it exposes large areas of stored water to evaporative loss that may equal what is gained as savings. Much attention is currently given to water efficiency through conservation and to underground evaporation-proof storage.

Like other aspects of climate, drought cannot be understood fully without reference to the context that brings weather toward or away from that spot. Ice extent and location in the polar regions and ocean temperatures in the lower latitudes have "teleconnected" effects around the earth. The main effects of El Niño on U.S. climate are understood: wetter winters in the southern tier from California to Florida, drier weather in the Pacific Northwest and northern Rockies and in the Ohio River Valley, with approximately opposing effects with La Niña, El Niño's opposite phase. Changes in the frequency or in the position of El Niño can lead to changes in the likelihood of drought.

In addition, the world's oceans have slowly warmed over the past 50 to 100 years, but not equally. The Pacific has warmed more on its western side than its eastern side, and this asymmetry in turn alters the large-scale circulation patterns that bring precipitation to different parts of North America. The rapid reduction of Arctic ice extent recently observed may also affect flow patterns at middle and high latitudes. Such changes in circulation patterns on hemispheric and regional scales can readily affect the storm trajectories and frequencies that ultimately provide or deny precipitation to an area, and likewise affect local water budgets and evapotranspiration via temperature or wind effects.

The climate we experience anywhere is the end result of an intimately connected system of systems that ultimately involves the whole of the earth. Despite this daunting challenge to our ability to understand its workings, there are many tantalizing bits of evidence that we can make useful predictions about aspects of its behavior. Drought prediction in many ways is simply climate prediction and rides on the back of our ability to advance this capacity.

TRACKING DROUGHT: TOOLS AND RESOURCES

Developing a strategy to mitigate drought risk and manage water resources for any location is dependent upon understanding the climate regimes and drought climatology for the specific area of interest. The challenges moving forward consist of having the best available data and assessment tools for decision makers, especially water resource managers and planning practitioners, to adequately plan and prepare for future drought events. With a changing climate, the ability to compare trends over the last several decades allows decision makers to contrast historical events with current drought conditions in order to make better-informed management decisions about drought risk in the future.

Climate data and drought indices are key components used to monitor drought. Since 1895 the National Climatic Data Center has computed monthly drought indices on a climate division scale for the entire United States. This technique is adequate for a generalized perspective on drought, but with each new drought event, the question comes up as to how the current drought compares to others historically for a specific location, county, or basin. Until recently, there have been few tools available to decision makers and scientists that evaluate drought on more a localized scale.

National Integrated Drought Information System

The National Integrated Drought Information System (NIDIS) was established by an act of Congress in 2006 to help begin to move the United States from a reactive response to drought to a proactive stance. NIDIS, led by the National Oceanic and Atmospheric Administration (NOAA), integrates the efforts of federal agencies as well as state and local drought-planning efforts. It is building a national drought early warning system that includes an extensive online collection of drought monitoring and planning tools as well as regional drought early warning systems. NIDIS engages with policy makers, researchers, and stakeholders through national, regional, and local events.

U.S. Drought Monitor

The U.S. Drought Monitor, a map produced each week showing the location and intensity of drought across the country, is a joint effort between the National Drought Mitigation Center (NDMC), the U.S. Department of Agriculture, NOAA, and a network of about 375 federal, state, and local observers across the country. Authors from each of those three organizations take two-week turns evaluating many streams of climatologic, hydrologic, and impact data and working with the network of reviewers across the country to produce the weekly map.

The NDMC has housed and maintained the U.S. Drought Monitor website since its launch in 1999. The map has become increasingly central to government responses to drought, with certain drought-disaster declarations now triggered automatically by U.S. Drought Monitor status. Media also use it for large-scale depictions of drought. Scientific research continually refines the data available for authors to consult.

Drought Risk Atlas

Decision makers have continuously asked for better decision-support tools and resources—including better drought-risk tools and resources—to help them better assess the risks related to climate variability and extremes (Jacobs 2002; Wilhite 2007). The first attempt at a nationally focused drought-risk tool was the National Drought Atlas (NDA), developed in 1994 by the U.S. Army Corps of Engineers, NOAA, and IBM (Willeke et al. 1994). The NDA used the United States Historical Climatology Network data culled from the Cooperative Observer Program of the National Weather Service (Karl et al. 1990). The number of stations originally used numbered 1,036 and data collection was focused primarily on hydrology and the Palmer Drought Severity Index, which was calculated from monthly precipitation totals.

With drought continuing to be one of the most problematic and costly natural disasters within the United States, the NDMC developed an updated and expanded Drought Risk Atlas (DRA) for the United States. The DRA provides a mechanism for research, decision making, and planning on both past and future drought episodes by providing climate data and drought indices at a more localized level (using a station-based approach) and on a more frequent time step. This tool increases planners' capacity to understand drought and to better identify past and present trends along with past, present, and future vulnerabilities to drought.

Among its functions, the DRA provides weekly and monthly calculations of multiple drought indices analyzing and incorporating more than 3,000 stations. It utilizes a much longer period of record, nearly doubling the original NDA period of record in most cases, and will eventually house approximately 500,000 gridded weekly drought-index maps (from the early 1900s to the present) along with a user interface that will allow for the analysis of various characteristics of drought such as severity, frequency, history, and spatial extent.

This enhanced DRA is intended to help decision makers (including policy makers and planners as well as water and natural resource managers) analyze the potential risk for drought in any particular area during any time of the year. Tailoring the DRA to the needs of planners and decision makers allowed for improvements in analyzing drought as an extreme event; data and visualization tools help users understand the frequency, historical context, magnitude, spatial extent, and trends of drought at the local community, basin, tribal, regional, or state levels. The tool's built-in spatial flexibility provides natural and water resource managers and planners a valuable feature to inform their constituents about how to better cope with climate variability and change at all scales and under various levels of risk or uncertainty.

Drought Management Database

Decision makers in various capacities can take preventive action to reduce the impacts of drought. The NDMC launched the Drought Management Database (DMD) in 2013 to provide recommendations for dealing with drought and to catalog the strategies being tried in different places. The database offers a collection of best practices categorized by eight sectors. The drought mitigation news feature on the homepage of the database also provides a way to highlight drought management news stories that turn up in the NDMC's automated daily search. The stories provide a glimpse of issues and strategies being implemented around the country.

The database categorizes strategies by eight primary sectors: energy, farming, fire, livestock production, plants and wildlife, recreation and tourism, society and public health, and water supply and quality. Users can refine searches using a number of filters such as subsectors, location, and geographic scope. Some scopes and sectors, such as those related to agriculture, benefit from well-developed networks of professional support; other scopes and sectors, such as energy or recreation and tourism, have fewer available resources, which may reflect a lower awareness of drought or disincentives to speak about it publicly.

Integrating drought planning into other types of planning—such as comprehensive, zoning, infrastructure, and multihazard plans—is a timely idea, particularly in light of the growing number of planning entities that are focusing on natural hazards and climate change. The NDMC hopes that this process of mainstreaming drought planning will yield a new crop of specific ideas that explicitly recognize the natural connections between land use and water.

Drought Impact Reporter

The Drought Impact Reporter (DIR) is another online resource that can help in drought planning. This comprehensive, web-based archive of drought impacts as reported by diverse sources has been online since 2005, and is updated in near-real time from media, government, and individual observers' reports. Similar to the DMD, the DIR categorizes reports and impacts by sectors: agriculture; business and industry; energy; fire; plants and wildlife; relief, response, and restrictions; society and public health; tourism and recreation; and water supply and quality.

The DIR can help planners research past effects of drought for specific locations. Impacts vary considerably from urban to rural areas, with many city dwellers experiencing drought mainly as it relates to lawn watering—the need for more water and utilities' requests for conservation. In rural areas, by contrast, people are more likely to experience a full range of impacts such as dry wells, curtailed agricultural or garden production, wildfire risk, or blowing dust. People may notice that water-based recreation, such as floating or fishing in rivers or boating on lakes, is curtailed due to lack of water; fish may die, and animals may venture further from their normal territories in search of food and water.

USING THE DROUGHT RESOURCES TOOLBOX

Establishment of NIDIS in 2006 was in part a recognition that communities can and should prepare for drought. Through the U.S. Drought Portal and many regional initiatives, NIDIS is enhancing the state of drought early-warning systems and helping develop the capacity to use them. The

U.S. Drought Monitor, established in 1999, provides a weekly big-picture assessment of the current state of drought in the United States. The DRA, launched in 2013, can provide planners with a detailed understanding of local drought climatology, answering questions such as how frequently drought visits a particular location, how long it has lasted, and how bad it has been. The DMD is a continually updated repository of strategies for dealing with drought by several different sectors and from many different angles. The DIR is a continually updated archive of the effects of drought.

These tools help provide answers that communities need in understanding drought risk and assessing possible long- and short-term strategies for reducing risk and responding to the next drought. Growing populations and consumption patterns and evolving environmental and climate constraints are making people more aware of the need to balance the supply and demand for water. Although planners cannot control the weather, they can control how water does and does not flow through the built and managed environments, which has some effect on the weather and is one form of long-term drought mitigation. They can also be prepared to scale back water needs or tap alternative supplies so that natural variation in water availability does not provoke a crisis.

PLANNERS' TOOLBOX: NATIONAL DROUGHT MITIGATION AND MONITORING RESOURCES

The website of the National Drought Mitigation Center (NDMC) (**drought.unl.edu**) has been compared to an online textbook for drought planning. It includes an overview of key concepts related to drought and drought planning and an extensive collection of state and local drought plans and resources (**drought.unl.edu/Planning/PlanningInfobyState.aspx**).

The NDMC has worked closely with the National Integrated Drought Information System (NIDIS) on the U.S. Drought Portal (**drought.gov**) as well as workshops and webinars for stakeholders, planners, and scientists, a national drought forum, and the establishment of regional drought early-warning systems. Questions or comments about NIDIS can be submitted through the contact form at **drought.gov/drought/contact**.

The U.S. Drought Monitor (**droughtmonitor.unl.edu**) is a national collaborative effort to synthesize multiple indices and impacts and produce a weekly map of drought conditions across the country. Questions about the U.S. Drought Monitor can be sent to **droughtmonitor@unl.edu**.

The newly completed Drought Risk Atlas (DRA) (**droughtatlas.unl.edu**) facilitates historic drought comparisons using climate station data. The Drought Management Database (DMD) (**drought.unl.edu/droughtmanagement/Home.aspx**), also recently launched, is a growing collection of planning strategies. These projects are ongoing and part of the NDMC's mission to disseminate information to help reduce societal vulnerability to drought. Comments or suggestions about the DRA or the DMD can be sent to **ndmc@unl.edu**.

Planners and stakeholders are encouraged to use and add to the Drought Impact Reporter (DIR) (**droughtreporter.unl.edu**), which has a collaborative mapping component. Additional local observations or summary reports in the DIR contribute to a better understanding of drought impacts across socioeconomic and environmental systems and help create a permanent record of impacts for both local and general use. Questions about the DIR can be sent to **dirinfo@unl.edu**.

CHAPTER 3

Drought: How Planners Can Address the Issue

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What can planners possibly do about drought? Like any other issue and many other natural hazards, drought poses certain constraints for an effective planning response. However, it should be equally clear from the foregoing discussion that drought poses opportunities for a planning response as well. This chapter will focus on those opportunities. It will discuss the specific types of plans that can address drought, along with their relative merits under different circumstances, the stakeholders who should be involved in the planning process, and ways to effectively explain and communicate drought-related issues.

What is clear is that many of the routine planning decisions communities make affect their resilience in responding to drought. Urban form influences water consumption in significant ways, as do building codes and landscaping choices. The precise impacts vary with climate, but regulations aimed at water conservation clearly can help communities cope better with drought. Both water management and land-use planning play roles in determining how well communities handle drought. Over time, the demonstrated ability of a community to manage water supplies in the face of scarcity affects its prospects for economic development, particularly with industries that require reliable water supplies.

HOW DROUGHT DIFFERS FROM OTHER HAZARDS

In the pantheon of natural hazards, drought has qualities that distinguish it from other events. Most people conceive of disasters as having clear beginnings and ends that are a dramatic contrast to the routine. The ground starts to rumble in an earthquake; a mountain explodes and becomes a volcano; the winds start to howl in cyclonic storms; or flood waters overflow the river banks and envelop homes and businesses. Each of these events includes some warning signs, a bit of elapsed time from onset to crescendo, and a conclusion. The amount of warning varies—almost none for earthquakes to perhaps 48 hours for hurricanes, and sometimes weeks of rumbles or slow erosion for volcanoes and landslides. Each hazard has particular characteristics that define the nature of the event.

Drought, however, is different in part because of the slow onset of the event. The start of an extended drought is never clear. Rather, the slow, steady accumulation of consecutive days without rain is what signals that a new pattern has taken hold. This is different from simple aridity, which is a climatic condition that defines average rainfall. Drought is a departure from the norm in the direction of persistent reduced precipitation, resulting in regional or even more widespread deprivation of anticipated water supplies. The Midwest floods of 1993 were distinguished by an unusual prolonged weather pattern of heavy rainfall that produced massive floods affecting nine states; drought is the antithesis of such a weather pattern. The insidious nature of the event is the simple fact that it begins slowly and almost unnoticed, gradually becoming an event of prolonged collective agony as communities pray for rain. By the time a community or region realizes it is experiencing drought, it may already have foregone many good opportunities to mitigate the event, unless it has planned effectively.

This suggests that the slow onset of drought is not its only distinguishing feature. In contrast to the other hazards described above, drought tends to lack clear parameters. No matter how severe a hurricane may be, its presence can last only days at most, and it will diminish or move on. In contrast, it is very difficult, in the midst of drought, to determine exactly when the event began and when it will end. Only when the rains arrive is there any indication that the pattern may end, and even one downpour, while providing relief, may not be a reliable indicator that the drought itself is at an end. Small rain events may merely be momentary breaks in the larger weather pattern. In addition, drought conditions are relative to normal precipitation for any given area. A region that normally expects 30 inches of rain per year is unquestionably experiencing drought if it endures two years of 10 and 12 inches, even though that much rain would be perfectly normal in a more arid environment, such as western Kansas or New Mexico.

What does all this mean for planning? When we know that a city is facing landfall of a hurricane or tropical storm within 24 hours, certain clearly defined emergency measures will (or should) kick in. These may include mandatory evacuations, road closures, the opening of shelters, and the protection of critical facilities. There are clearly defined mitigation measures available beforehand, such as the building or restoring of levees and the elevating of homes. Ideally, a recovery plan would focus on making the community more resilient in the face of future storms. With drought, however, a key issue involves knowing when to trigger the appropriate responses and emergency measures. The signals are less clear, even though with time they can become incredibly powerful—as reservoirs shrink, river levels decline, and wells run dry. When is it time to declare an emergency? The question itself suggests a role for preplanning during normal times in order to anticipate the event, consider when officials should pull the trigger on emergency and recovery responses, and decide what those responses should be and how effective they are likely to be.

Drought is a variation from a norm, and not an event that is measured by a universal standard such as hurricane or tornado wind speed. Therefore, drought plans at the local level must be customized to accommodate climatic variations. Additional factors are differences in water supply, closely tied to location, and water demand, related to demographics and the economic dimensions of a city or region. For instance, the impact of drought in the Midwest varies widely between inland cities and those bordering the Great Lakes, whose water supply may seem relatively inexhaustible (though drought will still create other problems even in cities like Chicago and Cleveland).

LAND-USE PLANNING ACTIVITIES RELATED TO DROUGHT MITIGATION

Integrating drought mitigation and climate change considerations into routine planning processes is an effective way to alert the community, bring resources together, and set systems in place before the onset of a full-blown water shortage. This early integrated planning can also build community resilience and facilitate a more rapid recovery from drought and other related hazards. Including water suppliers in the land-use planning process will allow for a synchronization of data, policies, actions, and resources. Likewise, involving land-use planning agencies in the water-shortage contingency planning of water suppliers is a way to avert conflicting policies and duplicative actions. By sharing data and other resources, land-use and water management agencies as well as the community as a whole can benefit.

To what extent do specific zoning and structural characteristics of urban development impact water consumption in a metropolitan region? How do demographic factors in combination with land-use patterns affect water consumption? Recent research in Portland, Oregon, explores these questions, shedding light on the potential impact of land-use planning on water conservation and the mitigation of drought (Shandas and Parandvash 2010). Portland's planning processes are similar to those of many urban areas in the U.S. in that the city includes "water" as an infrastructure subsystem in its land-use plan, but does not require new developments to ensure an adequate water supply into the future.

The researchers used GIS to integrate land-use records, water consumption data, sociodemographics, and property tax information for 122,550 parcels to measure the effect of urban form on regional water demand. Findings include the following:

- For every one acre of additional multifamily residential development built, an additional 3.9 acre-feet of water is required.
- For every one acre of additional single-family residential development built, an additional 3.8 acre-feet of water is required.
- For every one acre of additional commercial-industrial development built, an additional 1.65 acre-feet of water is required.

- An increase of 100 square feet of single-family residential development resulted in an increase of almost 3 acre-feet of water consumed per year.
- A $1,000 increase in median income per block group resulted in a 0.14 acre-foot increase in water consumption.
- An increase of 100 college-educated residents per block group resulted in a 0.2 acre-foot reduction in water consumption.

For new single-family residential developments, based on this analysis, the researchers estimate that a 25 percent reduction in the average building size in the study region is associated with a 20.3 acre-foot reduction in water consumption per year. Also, for a new subdivision of 100 homes, a 25 percent increase in the number of households per acre, from four to five households per acre, would reduce cumulative water consumption by approximately 126 acre-feet.

In terms of affecting change in water-use patterns in existing developments, the researchers suggest that planning agencies have greater access to the urban citizenry than do water management agencies and should take the lead in public outreach activities, especially for single-family and multifamily residential developments. They believe that addressing behavioral aspects of water conservation in existing developments would be the most productive avenue of change.

In the researchers' conclusion, they recommend the adoption of

> a fully integrated approach . . . [for establishing frameworks] defining the legal responsibilities of urban planning and water resource management agencies. These frameworks may develop as formalized agreements, comprehensive plans with explicit water management sections and/or long-term urban management plans that mandate the integration of land use planning with water management policies. Because water resource availability affects the economic, ecological, and human health of a region, such integrative approaches will become increasingly necessary as pressures from urban development and climate variability place greater stress on the natural resources upon which we depend. (Shandas and Parandvash 2009)

In accordance with the Portland research findings that smaller home sizes lessened water use, a study by the U.S. Environmental Protection Agency found that in Utah, where 60 percent of residential water use is for watering lawns and landscaping, households on 0.2-acre lots use only half as much water as those on 0.5-acre lots. During the peak irrigation season in Seattle, households on 0.15-acre lots use 60 percent less water than those on 0.37-acre lots (Western Resources Advocates 2003).

Of course, each community's own set of infrastructure, demographic, environmental, social, political, and cultural conditions will affect the relationship between land-use and water-use patterns. This example suggests some of the potential benefits associated with agencies working in concert to prepare a community for drought, to build in drought resilience, and to mitigate the anticipated hazards of climate change.

In addition to general plan, area plan, functional plan, and operation plan responsibilities, as well as zoning and regulatory functions, local government agencies have the authority to adopt codes and ordinances. Plumbing codes related to water-efficient devices and fixtures have been very effective in reducing water use. State and local water- and energy-efficiency standards have also contributed to more sustainable communities. Likewise, water-efficient landscape ordinances are tools employed by local governments to design sustainable, low water-using landscapes. An example from California highlights the importance of local planning agencies' water-efficient landscape ordinances in the establishment of drought-resistant urban landscapes.

In 1990, the third year of a drought, the California legislature called for the development of a model water-efficient landscape ordinance. The State Model Ordinance set a "maximum applied water allowance," a landscape water budget based on the square footage of the landscape and the climate of the region, as an upper limit for the water use of a specific landscape. Also included in the ordinance are irrigation equipment efficiency, hydrozoning (grouping plants based on their relative water needs), and other specific requirements. This state law was updated in 2006 to require cities and counties to adopt local ordinances that are "at least as effective as" the State Model Ordinance.

Local governments were encouraged to work with their water suppliers in the development of local water-efficient landscape ordinances and, likewise, water suppliers were encouraged to participate in the process. The water suppliers have resources useful to planners such as water-use data and staff that are technically trained regarding water-efficient landscapes. They also have water conservation materials and websites to assist their customers in developing, installing, and maintaining water-efficient landscapes. Planners, in turn, collect and maintain valuable information about the dimensions of developments' landscaped areas and other demographic data that water suppliers need to design their water management and drought mitigation programs.

In many cases, local governments and water districts recognized the benefits of working together on a regional basis to adopt one regional or several consistent local landscape ordinances. For example, the Inland Empire Utilities Agency, a wholesale water supplier in Southern California, formed an alliance of 13 local planning agencies that worked collaboratively to develop and implement an effective regional ordinance. The local water suppliers in the region participated actively in the process as well. In the San Francisco Bay Area, Build It Green and StopWaste.com, two community-based organizations, worked with planners, water districts, and sustainability interests to collaborate and coordinate their efforts related to landscape ordinances.

When local planning departments build in water efficiency right from the design and installation phase through the local planning and development phase, water suppliers can then better meet their responsibilities to encourage long-term efficient water management at those properties. The next section discusses types of plans and some of the functions of water suppliers related to general water management and water-shortage contingency planning. Winning public support for these plans, however, will require effective explanations of the importance of mitigating drought.

TYPES OF PLANS FOR ADDRESSING DROUGHT

Planners are accustomed to using a variety of plan types for a variety of purposes. While the comprehensive plan (also known as master or general plan) is a vehicle for integrating a wide range of considerations into community planning and for thinking more comprehensively, plans specifically focused on particular functions or subareas within a community are also part of the planner's toolbox. Some of these plans may specifically address drought; others address hazards more generally, or address anticipated changes in the urban climate as a result of climate change. It is important for planners in any community to assess what combination of tools is best suited to solve that community's unique problems. The intent of this section is to review the utility of these options and how addressing drought fits within their purview.

Stand-Alone Drought Plans

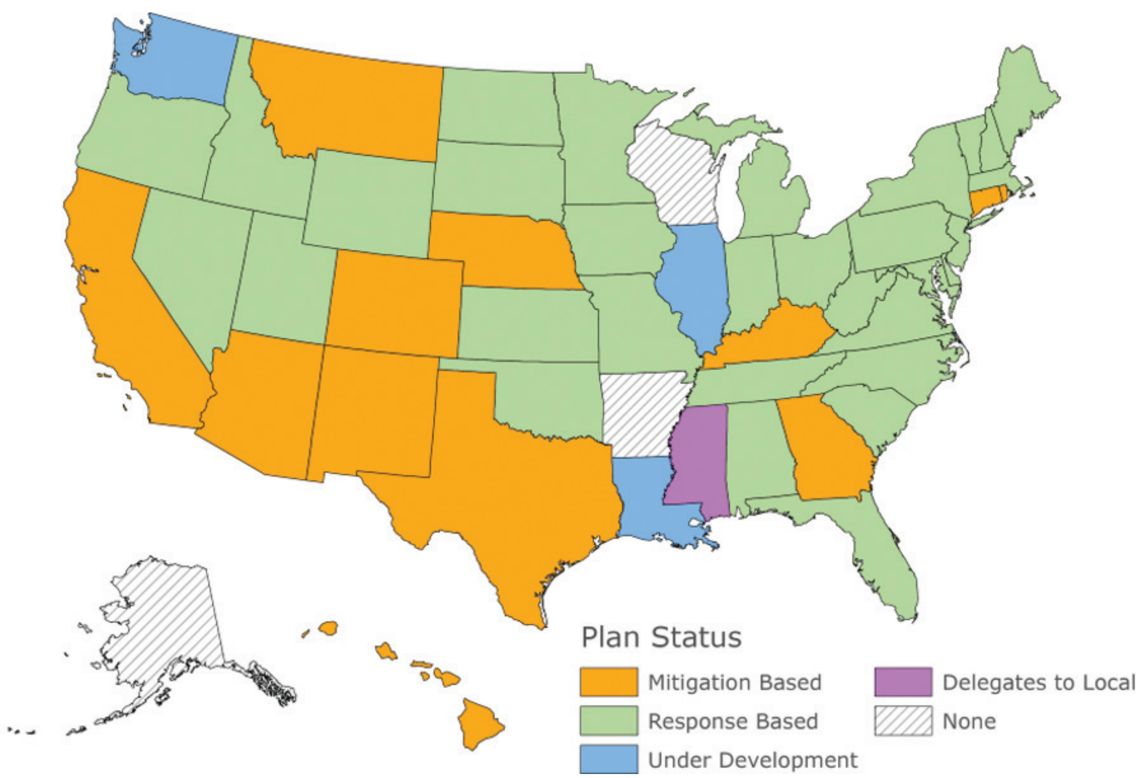
Drought planning is defined by the National Drought Mitigation Center (NDMC) as actions taken by individual citizens, industry, government, and others before drought occurs to reduce or mitigate impacts and conflicts arising from drought. There are several planning mechanisms that can address drought. A stand-alone drought plan is typically the most comprehensive way to plan for drought.

The NDMC categorizes drought plans as mitigation plans or response plans. Drought mitigation refers to actions taken in advance of a drought that reduce potential drought-related impacts when the event occurs. Drought response planning addresses actions that should be taken in response to emerging and ongoing drought. Ideally, stand-alone drought plans should incorporate both mitigation and response. The NDMC recommends that authorities at all levels—state, local, and tribal governments, water suppliers, and regional organizations—investigate the feasibility of drought planning.

States are sovereign governments with authority to pass laws regulating water use, so they play a key role in planning for drought in the United States. Most drought plans at the state level have been primarily focused on monitoring and response, but many are beginning to incorporate mitigation as they are updated. NDMC has been tracking the status of drought planning at the state and local levels. Figure 3.1 indicates which states have drought plans, and if so, whether the plans emphasize mitigation or response. Many water suppliers as well as regional, tribal, and local governments have also developed drought plans. In fact, plans that are more limited in their geographic scope may be better able to address specific stakeholder needs in a tangible way that higher-level plans cannot.

Figure 3.1. *Status of state drought plans*

Source: NDMC 2013



While a variety of stand-alone drought planning processes exist, they all incorporate certain key elements.

Leadership. Many plans utilize a drought task force as the foundation of the planning team. Some processes divide the planning team into subcommittees organized around impact sectors such as agriculture, water supply, municipal and industrial development, wildlife, or tourism. These groups may be charged with identifying potential and emerging impacts and performing vulnerability assessments, and they may suggest potential management options to the drought task force. Often, another subgroup of the task force will become a standing monitoring committee that will periodically assess climate and weather trends and report on potential concerns or impacts.

Monitoring and Early Warning. Planning for and managing drought requires diligent monitoring of a variety of dynamic water availability and climate factors in order to gauge the severity of drought. The severity of droughts is typically related to the following:

- magnitude (how large the water deficits are in comparison to historical averages)
- duration (how long the drought lasts)
- areal extent (what area is impacted by the drought)

Most drought plans incorporate some aspect of monitoring and early warning in order to initiate response or mitigation actions. For example, a municipality may initiate water restrictions when its water supply reservoir reaches a certain level. A good monitoring plan typically includes specific provisions for communicating with the rest of the drought planning team, groups or agencies with particular interests, and the general public. During times of plentiful water supply, monitoring may simply consist of a monthly or quarterly confirmation that water supplies are adequate. One of the key responsibilities of the monitoring group is knowing how drought will manifest itself for that particular time and place. The NDMC recommends that each drought planning effort establish an operational definition of drought by knowing what metrics are relevant and what readings may indicate an emerging drought. Two useful drought monitoring tools are the NDMC's U.S. Drought Monitor (droughtmonitor.unl.edu), a national monitoring resource updated each week, and the Drought Risk Atlas (droughtatlas.unl.edu), a resource that helps facilitate comparisons between present and past conditions.

Vulnerability Assessment. Most drought planning processes include analysis of past impacts to identify causes of underlying vulnerability. For example, a community that found its ability to deliver drinking water imperiled because of a high proportion of available water going to lawn irrigation might in the future choose to curtail lawn watering earlier in a drought (a response action) or pass an ordinance that allows or encourages xeriscaping (a mitigation action). The vulnerability assessment may also include a review of water supply reliability planning efforts. Information from water supply reliability planning may be useful in identifying drought trigger mechanisms and response targets. Depending on recent drought experience, stakeholders may have fresh memories of impacts and vulnerability and good senses of what needs to be done to prevent similar experiences during the next drought, or people may need to delve into local historical archives to learn about how drought has affected the community in the past. If the most recent drought occurred more than several years ago, it is particularly important to consider how changes in land use, demographics, climate, and other factors may play into the next drought. The NDMC's Drought Impact Reporter (droughtreporter.unl.edu) may help local planners identify and understand the range of potential impacts based on the recent experiences of other communities.

Communication, Education, and Outreach. Most drought plans include provisions for public education so that people will understand the area's water supply and vulnerability to drought, and the ways in which their personal choices may affect both collective and individual well-being during drought. People may be more likely to respond favorably to requests to conserve water when they are not learning about vulnerability for the first time during a drought. Plans also include provisions for communication, particularly during drought. Note that public water suppliers may need to request very specific behavior changes during drought, so messages should be coordinated between various entities. Because media markets may not coincide with utility service areas, messages in water bills or other direct communication with customers may be a necessary component of communication.

Identification of Drought Mitigation Actions. Ideally, a drought plan should include lists of actions to be taken in response to future drought. More importantly for urban planners, it should also offer lists of long-term changes that can reduce vulnerability to future droughts. Many changes related to land use or water infrastructure could take years or even decades to implement, and would also need to be incorporated into infrastructure planning, zoning regulations, and comprehensive planning. In this case, drought planning dovetails well with climate change adaptation planning. For example, smart-growth measures that reduce paved area and vehicle miles traveled can mitigate climate change (i.e., reduce carbon emissions, and reduce vulnerability to drought by improving the moisture-absorbing capacity of the land area). The NDMC's Drought Management Database (droughtdev.unl.edu/droughtmanagement/HOME.aspx) offers a source of ideas from other communities' experiences.

Identification of Phased Responses. Drought plans typically include phases or stages that summarize specific actions to undertake when drought conditions worsen. Figure 3.2 graphically depicts the general sequence of events of the Colorado Drought Response Plan and illustrates how components of the plan are activated and deactivated as the drought intensifies, then subsides. Each phase includes severity indices that are intended to provide a general framework and by themselves do not initiate response actions.

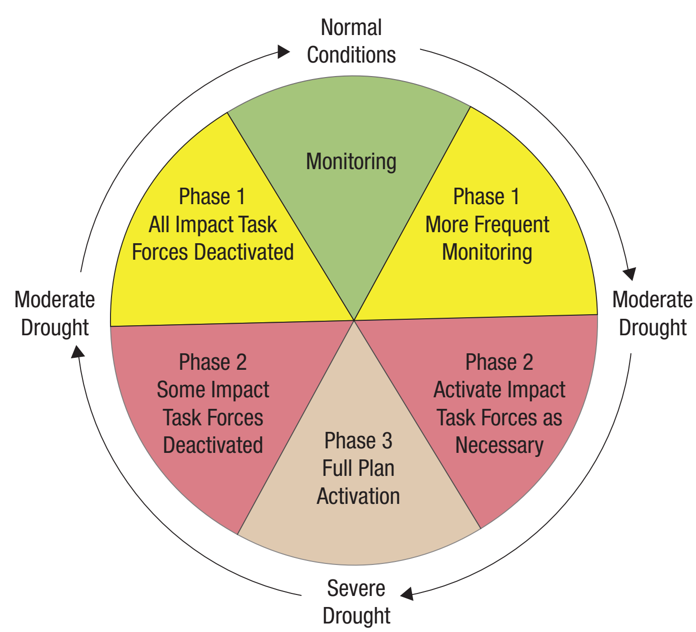


Figure 3.2. *Colorado drought response plan*

Source: CWCB 2010a

Outlining "triggers" for response actions based on drought indicators is a useful exercise and may help guide decision making, but it may be problematic if response actions are not evaluated from all angles prior to implementation. Further data analysis may be required to fully understand impacts of abnormally dry conditions suggested by the indicators. Recommendations for action may also depend on timing, extent, water supply, and expert judgment. Political realities are typically such that governors, mayors, and other officials prefer to assess response actions in the context of the political climate and current public sentiment. Table 3.1 offers an example of sample long- and short-term drought mitigation and response actions from the Colorado plan.

TABLE 3.1. DROUGHT MITIGATION AND RESPONSE ACTIONS

Mitigation and Response Actions	Long-Term Mitigation	Short-Term Response Actions
Elements of a Drought Management Plan		
Establish drought response principles, objectives, and priorities	X	
Establish authority and process for declaring a drought emergency	X	
Develop drought stages, trigger points, and response targets	X	
Prepare ordinances on drought measures	X	
Evaluate historical drought impacts	X	
Monitor drought indicators (e.g., snow pack and stream flow)	X	X
Monitor water quality	X	X
Track public perception and effectiveness of drought measures	X	X
Improve accuracy of runoff and water supply forecasts	X	
Emergency Response		
Declare a drought emergency		X
Establish water hauling programs	X	X
Restrict/prohibit new taps		X
Identify state and federal assistance	X	X
Provide emergency water to domestic well users		X
Import water by truck/train		X
Public Education and Relations		
Establish a public advisory committee during drought planning and/or drought response efforts	X	X
Develop drought public education campaign with long-term and short-term strategies	X	X
Educate provider/municipal staff on how to save water	X	X
Provide instructional resources to businesses on developing business-specific drought mitigation and response plans	X	X
Provide acoustical meters to assist customers in identifying leaks	X	X
Water Supply Augmentation		
Establish drought reserves	X	
Draw from drought reserves		X
Increase groundwater pumping		X

Source: Colorado Drought Mitigation and Response Plan, Annex B

RESOURCES: DROUGHT MITIGATION AND RESPONSE PLANNING

Dr. Donald A. Wilhite's 10-step process for drought planning is described in detail in "Drought Preparedness Planning: Building Institutional Capacity," published as a chapter in *Drought and Water Crises: Science, Technology, and Management Issues* (Wilhite et al. 2005). It is available at **drought.unl.edu/portals/0/docs/10StepProcess.pdf**.

Recognizing the need to provide drought-planning guidance for smaller communities that might not have the capacity to undertake the 10-step process, the National Drought Mitigation Center and partners developed the guidebook *Drought-Ready Communities: A Guide to Community Drought Preparedness*, a project sponsored by the Sectoral Applications Research Program of the National Oceanic and Atmospheric Administration (NDMC 2011). The guide adapts the principles developed in the 10-step process for use at the municipal level. It simplifies the process around the basic steps of developing an inclusive leadership team; establishing monitoring processes; working with sector or community representatives to assess vulnerability and monitor impacts; conducting public education and communication; and developing a plan. The guide includes case studies and an extensive resource collection about other municipalities' plans for drought, including both processes and solutions. It is available at **drought.unl.edu/Planning/PlanningProcesses/DroughtReadyCommunities.aspx**.

In response to widespread drought in 2012, the Extension Disaster Education Network and National Voluntary Organizations Active in Disaster developed the Community Capacity-Building Program for Drought Response, which was in pilot-testing as of 2013. This program, based on research and experience with long-term recovery efforts in past disasters, is described as being "designed for leaders who want to bring a community together to assess drought impacts and explore actions to combat the drought." It incorporates the impacts inventory from the 10-step process and the *Drought-Ready Communities* guidebook, but it is less technical. It focuses more on community opportunities for response that exist in the immediate aftermath of a drought, a time frame that makes monitoring a moot point. The program offers a guidebook, a digital presentation, and an introductory webinar. It is available at **eden.lsu.edu/EDENCourses/CCBPDR/Pages/default.aspx**.

As a component of the State Drought Plan Update in 2010, the Colorado Water Conservation Board (CWCB) developed the *Municipal Drought Management Plan Guidance Document* for municipalities and local governments to use when developing local drought mitigation and response plans. It recommends an eight-step planning process that incorporates vulnerability assessment, implementation and monitoring, and staged drought response plans as well as worksheets for identifying mitigation measures. A "Sample Drought Management Plan" companion document provides an example of a typical drought plan in Colorado. The CWCB also developed a web-based "drought toolbox" that includes resources in support of local drought management plans. The toolbox and CWCB documents are available at **cwcb.state.co.us/technical-resources/drought-planning-toolbox/Pages/main.aspx**.

Other guidance documents for drought planning include the *California Urban Drought Guidebook* from the State of California's Department of Water Resources (water.ca.gov/pubs/planning/urban_drought_guidebook/urban_drought_guidebook_2008.pdf) and the American Water Works Association's manual *Drought Preparedness and Response* (**www.awwa.org/store/productdetail.aspx?productid=26750**).

Drought-planning guidelines exist for states, municipalities, and water suppliers, and for municipal water suppliers within specific states. Effective plans often incorporate elements of a 10-step plan process originally developed by Dr. Donald A. Wilhite, a climatologist who worked extensively with states on drought planning in the 1980s to codify the process. Wilhite established the NDMC at the University of Nebraska-Lincoln in 1995, and he has promoted the use and adaptation of the 10-step process across the country and around the world (Wilhite, Hayes, and Knutson 2005). Plans that follow these steps can be tailored to the needs of an individual region, state, or country. The steps are:

1. Appoint a drought task force.
2. Define the purpose and objectives of the drought plan.
3. Anticipate and resolve conflicts between different water users.
4. Identify natural, human, and biological resources as well as financial and legal constraints.
5. Develop a drought plan that includes monitoring, impact assessment, and decision making.
6. Identify research and institutional needs.
7. Integrate science and policy perspectives.
8. Announce and test drought plan.
9. Teach the general public and the media about drought and water supply.
10. Keep the drought plan up to date, and evaluate it after droughts.

Planning for a complex problem such as drought should be approached in as holistic a manner as possible. One advantage of stand-alone drought plans is that they serve as a mechanism to coordinate with the variety of sectors that could be impacted by drought, which includes a mix of stakeholders that are not typically brought to the same table in other plans.

Local Hazard Mitigation Plans

Another option for addressing drought hazards is within the context of local hazard mitigation plans (LHMP). In order to be compliant with the Disaster Mitigation Act of 2000, a LHMP needs to contain a hazard identification and risk assessment (HIRA) and mitigation strategy. Drought should already be identified as a hazard within any comprehensive LHMP, as no jurisdiction is completely immune. The HIRA typically includes a profile of the hazard—a discussion of the nature, extent, past and potential impacts, and frequency of recurrence. The LHMP hazard profile is a good starting point for communities to document historic drought incidents and begin assessing the potential for future impacts.

LHMPs also contain a vulnerability assessment, which is an attempt to quantify the specific impacts of the hazard on people, property, and the built environment as well as an outlook on impacts to future development. This is where drought becomes a challenge for mitigation planners, as assessing and modeling impacts are not as straightforward as for other hazards, such as flood, where a defined hazard extent may exist. There is no common method for assessing drought vulnerability, and LHMPs typically focus on impacts to built structures and critical facilities and infrastructure, which are not typically affected by drought except in more extreme circumstances and about which good data on impacts are typically lacking.

Drought is not a hazard in which the Federal Emergency Management Agency typically invests funding for mitigation or response. Thus, many communities tend not to address the hazard in much detail within their LHMP. When drought is discussed, the impacts are usually focused on agriculture. This is partially due to perceptions that drought affects agriculture most strongly, but also due to the fact that the best available impact data are associated with agriculture. Crop insurance data can be obtained from the USDA Risk Management Agency back to 1948 (www.rma.usda.gov/data/cause.html). The data are categorized by the cause of the crop loss, which includes drought. These data can be summarized as an indication of potential losses from drought. A variety of agricultural statistics can usually be obtained from federal, state, and local agencies. The economic yields from crops and livestock in a typical year can be compared against drought years to quantify the amount and types of losses experienced in the past. If a LHMP attempts to quantify drought losses, it is usually in this context; otherwise, the vulnerability of other assets is usually discussed in qualitative terms.

The mitigation action strategy sections of LHMPs provide an opportunity to capture and prioritize short- and long-term drought mitigation activities. The action strategies in mitigation plans typically include the lead agency for implementation, time frame, costs, and relative benefits of a proposed strategy. As an example, this could include multihazard public education campaigns that could be leveraged to raise awareness of drought hazards and the importance of water conservation as a mitigation measure. Communities could address drought mitigation in their LHMPs and drought response within the context of emergency operations plans or separate drought response plans.

Some LHMPs contain a capability assessment, which includes an inventory of plans, policies, procedures, and personnel that have a role in hazard mitigation. The LHMP capability assessment should reference any existing drought response plans, water conservation plans, comprehensive plans, climate adaptation plans, water conservation ordinances, or water supply plans that address drought. LHMPs must address implementation of the plan through existing mechanisms, and the capability assessment assists with identifying the drought mitigation resources already in place that could be leveraged.

Water Management and Water Shortage Contingency Planning

According to the NDMC, all except three states (Alaska, Arkansas, and Wisconsin) have some sort of statewide drought plan (NDMC 2013). However, the major legal and regulatory responsibility for water management planning and drought preparedness rests primarily on local water suppliers. Federal, state, and regional entities also play a role. The following are descriptions of the four levels of responsibility—federal, state, regional, and local—using California as an example.

Federal Water Planning Requirements. The U.S. Bureau of Reclamation's Mid-Pacific region covers the majority of California. Federal regulations require that all urban water suppliers and agricultural irrigation districts in this region serving 2,000 acre-feet or more per year or with more than 2,000 connections complete water management plans. One section of these plans is dedicated to the contractor's water shortage allocation policies. Contractors are asked to describe such policies, including how reduced water supplies would be allocated to their customers.

Statewide Water Management Planning. The California Department of Water Resource's California Water Plan Update provides a framework for water managers, legislators, and the public to consider options and make decisions regarding California's water future. The plan is updated every five years through a public process that involves many stakeholders. The most recent version of the state's water plan, California Water Plan Update 2009, contained an expanded section on drought and the potential impact of global climate change on California's water supply (California Department of Water Resources 2009). The 2013 update, now in the works, will include an improved discussion of climate change, with greater detail, regionally specific climate-change information, and adaptation and mitigation strategies. It emphasizes that future water demand is affected by a number of growth and land-use factors like population growth, planting decisions by farmers, and size and type of urban landscapes. The chapter titled "Managing an Uncertain Future" emphasizes the need for decision makers, water and resource managers, and land-use planners to include a wide range of considerations in planning for California's water future.

Regional Water Management Planning. California's Integrated Regional Water Management (IRWM) planning is a collaborative effort to manage all aspects of water resources in a region. IRWM planning crosses jurisdictional, watershed, and political boundaries, and it involves multiple agencies, stakeholders, groups, and individuals. The goal of this process is to address the issues and differing perspectives of all the entities involved through mutually beneficial solutions.

Water supply reliability is the first water management strategy to be considered in these integrated plans. Meeting dry-year demands is often a high priority. Urban water management plans, prepared by local water utilities within the region, provide an important foundation for IRWM plans.

Local Water Management Planning. California requires all local water suppliers over a certain size to develop and implement Urban Water Management Plans (UWMPs). Water suppliers update their UWMPs every five years. Since 1983, every urban water supplier providing over 3,000 acre-feet of water annually or serving 3,000 or more connections is required to make every effort to ensure the appropriate level of reliability in its water service sufficient to meet the needs of its various categories of customers during normal, dry, and multiple dry years. A further requirement is that each water supplier must prepare a water shortage contingency plan.

The water shortage contingency plan includes six components:

1. A description of the stages of action an agency will take in response to water shortages
2. An estimate of supply for three consecutive dry years
3. A plan for dealing with a catastrophic supply interruption
4. A listing of the prohibitions, penalties, and consumption reduction methods to be employed
5. An analysis of anticipated revenue impacts of reduced sales during shortages
6. The process to be used to monitor and document water cutbacks

In addition to the importance of UWMPs to regional water management plans, the UWMPs also form a reference point for land-use planning. Since the passage of Senate Bills 610 and 221 in 2001, the approvals of large new developments in California must be linked to assurances that there is an adequate water supply. If a proposed project was not accounted for in the most recently adopted UWMP, the developer is required to determine whether the water supplier's total projected water supplies available during normal, single-dry, and multiple-dry water years during a 20-year time frame will meet the projected water demand associated with the proposed project. Without assurances that there is a reliable source of water, even in dry years, large development projects cannot proceed.

In January 2008, a local water supplier in Southern California for the first time postponed issuance of a "will-serve" letter (a promise to developers to provide water to a major urban development) because the district could not guarantee water for the next 20 years as required by the 2001 California law. Even though the law pertains only to very large development projects, this action certainly caught the attention of land-use planners. Since then, more water suppliers have begun to consider holding off on will-serve letters for new projects in water-scarce regions.

As important as it is for land-use planners to work with water suppliers to mitigate water shortages, the consideration of climate change in all planning activities—land and water—is becoming even more pressing. The next section examines the impacts of climate change on traditional planning processes.

ADDRESSING THE IMPACTS OF CLIMATE CHANGE

Planners and water managers can work together to deal with the impact of the hazards of extreme weather events and patterns, whether from natural climate variations or the effect of human-induced climate change. Extreme weather events, such as heat waves, wildfires, droughts, and floods, may be early signs of climate change. Rising sea levels, increased average temperatures, more extreme hot days, and changes in precipitation are evident across the country.

Some catastrophic events, while not predictable over the long term, can be mitigated early on through appropriate land-use planning and zoning policies. The recovery from such events can be accelerated when water management plans for repairing damaged water-distribution systems, restoring water treatment facilities, and controlling contamination problems are in place and ready for rapid implementation.

UPDATING CALIFORNIA'S *URBAN DROUGHT GUIDEBOOK*

One of the driest water years in California history was 2006–2007. The Colorado River basin had experienced drought seven of the eight previous years and, with potentially stringent new restrictions on pumping water through the San Francisco–San Joaquin Delta, the U.S. Bureau of Reclamation, California Department of Water Resources, and California Urban Water Conservation Council joined forces to sponsor 11 drought workshops and produce an updated 2008 version of the California Department of Water Resources' *Urban Drought Guidebook*. Representation from local governments as well as water districts was high, with 564 attendees at the free workshops.

Participants raised 10 common issues at the workshops and presented recommendations for overcoming various challenges such as lack of consistent data and staffing shortages. The following is the issue and recommendation regarding coordination between planning departments and water suppliers.

Issue: The disconnect between planning departments and water suppliers, even within the same city government, continues to stymie efforts to develop new projects with built-in water efficiency and to enforce landscape ordinances. Furthermore, conflicting state and local regulations and policies—especially those concerning state housing mandates and the ability to serve water, and especially during times of water shortages—need to be addressed.

Recommendation: Increase awareness and find resolutions for issues regarding conflicting state and local policies related to development, housing quotas, and water supply reliability.

Climate change intensifies the impacts of many natural hazards, including drought. However, it is not at all contradictory to expect *both* drought and high-precipitation events and extreme storms as a result of climate change. In 2012 alone, the pervasive incidence of drought in the Midwest and the floods and other hazards associated with Superstorm Sandy in the mid-Atlantic states created significant human suffering and economic losses. The examples that follow are intended to illustrate these contrasting extremes.

Recent U.S. Drought Experience

In 2012 the U.S. experienced a massive drought that at its peak on September 25 covered 65.5 percent of the country's contiguous land area, a new high in the 1999–2012 record. River basins experienced unusually dry conditions, with the Upper Colorado having its driest year on record since 1895. The drought also contributed to low water issues in the Great Lakes and Missouri and Mississippi rivers, threatening navigation on the latter (NCDC 2013). At the end of September, just one-quarter of planted corn was rated in good or excellent condition as compared to over half the year before (Adonizio, Kook, and Royales 2012).

Less publicized and less visibly linked effects of climate change are occurring more often. While temperature increases are expected in most regions, both urban and rural, even greater spikes of up to 10 to 20 degrees are anticipated in "heat islands"—areas with high concentrations of concrete and asphalt that radiate heat and have few shade trees to reduce the impact. This phenomenon often occurs in denser, lower-income neighborhoods with lower percentages of tree canopy. This can have a devastating effect on a community. In 2006, during a heat wave in California, county coroners reported 147 heat-related deaths. Some researchers, however, believe the number was up to three times more, with possibly 200 to 500 people dying as a result of that heat wave (Ostro et al. 2009).

More recently, the City of Chicago instituted a program to establish cooling stations during extreme heat spells after residents suffered from a lengthy heat spell in 2006. In 2011, at the onset of another heat spell, the city set up six cooling stations in low-income neighborhoods and urged people to check on seniors and other isolated individuals. Having these measures in place based on their community plan, Chicago was able to prevent serious loss of life.

While drought planning is traditionally carried out by local water suppliers, consultation with planners early on can avoid or reduce the impact of drought on citizens, businesses, agriculture, and the environment. Demographic, geographic, and economic data that planners maintain, in turn, can be very useful to water managers' efforts to allocate short water supplies efficiently and equitably.

Superstorm Sandy

In 2013 Superstorm Sandy became the largest Atlantic hurricane on record. Economic losses are estimated at $65.6 billion, which would make it the second-costliest Atlantic hurricane behind only Hurricane Katrina. At least 253 people were killed along the path of the storm in seven countries, including Haiti, Cuba, and the Bahamas.

Sandy was a product of an unfortunate alignment of several natural factors associated with the weather as well as human influences. The sea surface temperatures were 5°F above the 30-year average for that time of year, and 1°F of that was very likely a direct result of global warming. With every 1°F rise in temperature, the atmosphere can hold four percent more moisture. Thus, Sandy was able to gather greater-than-usual amounts of moisture, fueling a stronger storm and magnifying the amount of rainfall by 5 to 10 percent compared with conditions more than 40 years ago. Climate change has also led to a continual rise in sea levels, currently at a rate of just over one foot per century, providing a higher base level from which the storm surge operated (Trenberth 2012).

Extensive coverage of Hurricane Sandy suggests that the heavy impact of the storm was due in part to ongoing land-use policy and regulations that allowed development in vulnerable coastal locations in New York and New Jersey:

> A pell-mell, decades-long rush to throw up housing and businesses along fragile and vulnerable coastlines trumped commonsense concerns about the wisdom of placing hundreds of thousands of closely huddled people in the path of potential cataclysms.
>
> Experts also suggest there's another interim step just awaiting the political will to see it through: stop building more homes and businesses where they too will require protection. . . . Still, the state [of New Jersey] has spent disproportionate amounts of money on short-term coastal protection projects rather than pursuing . . . buyout programs that discourage new development in the most hazardous areas. (Rudolf et al. 2012)

But perhaps change is in the wind for low-lying development, at least in New York State. On February 2, 2013, the *New York Times* reported that Governor Cuomo is proposing to spend $400 million to purchase homes wrecked by Superstorm Sandy, demolish them, and then preserve the flood-prone land permanently as undeveloped coastline. If approved by federal officials, owners of the 10,000 or so homes in the 100-year flood plain would be offered payouts at the pre-storm full market value of their houses (Kaplan 2013).

Climate Change Impacts on the West Coast

West Coast communities are also facing the perils of the impending rise in sea levels and potential saltwater intrusion into coastal freshwater aquifers. The Bay Conservation and Development Commission, established in the 1960s, has permitting and enforcement authority over any project within 100 feet of the shoreline, working with counties and cities on waterfront planning initiatives. But today the commission's original charter —to keep vast portions of San Francisco Bay from being filled by subdivisions—is less of a focus than dealing with rising sea levels. Prevailing scenarios envision that water levels in the bay could rise by more than five feet between now and 2100. This new focus was made clear when the commission updated its Bay Plan in 2011 to emphasize the need for "a comprehensive regional strategy that deals with all the impacts of climate change" (King 2013).

When conditions change dramatically, the function of long-established institutions must realign, as the commission is in the process of doing. At such times of increasing uncertainty, there are new opportunities and an increasing need to build alliances among the various parties that share in the risks associated with climate change.

As demonstrated by these events, to mitigate and adapt to evolving climate patterns it is essential to include—and ideally to integrate—land-use practices and water management measures in the planning process. The key word associated with climate change is "extreme." Extended and intensified drought hazards associated with climate change are not as dramatically visible as an event like Superstorm Sandy; however, the cumulative economic losses and personal suffering can be significant.

While planners and water managers traditionally may have included elements in their plans related to drought and other hazards such as floods, wildfires, and extended heat events, taking a broader, longer-range, and cross-jurisdictional look at the potential impacts and mitigation measures related to extreme versions of those hazards is increasingly important.

California cities and counties are required to adopt climate action plans to reduce their carbon footprint by Assembly Bill 32, the Global Warming Solutions Act (AB 32 2006). These plans focus primarily on energy issues, but since a considerable amount of energy is required to pump, treat, and distribute water in the state, water use plays strongly into such plans. Water suppliers have no such requirement except to mention climate change in their UWMPs.

CROSS-JURISDICTIONAL PARTNERSHIPS FOR DROUGHT AND WATER PLANNING

Productive cross-jurisdictional partnerships are vital in helping to mitigate drought and climate change; they help foster communication, coordination, and collaboration among planners, water suppliers, and other stakeholders. Many local agencies are already practicing compact sustainable development in their communities. Efforts to reduce a community's energy use and greenhouse gas emissions, such as the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) program, increasingly include complementary water efficiency measures as described in the *Smart Water Report* by Western Resource Advocates:

> A case study from Tucson shows that astounding water savings can be realized if new urban and suburban developments incorporate mixed uses, higher densities, water reuse, and water-efficient Xeriscape landscape design and irrigation practices. In sum, water use resulting from urban sprawl can be reduced by modifications to development densities (e.g., lot sizes), the chosen type of developed landscape, and the source of landscape irrigation water.
>
> Municipal zoning ordinances, land development standards, comprehensive plans, and inter-municipal regional plans all play key roles in creating sustainable development and, as a result, more sustainable water use. (Western Resource Associates 2003)

Finding the intersection between compact sustainable land-use planning and integrated regional water management planning, and ensuring that they complement rather than conflict with each other, is the challenge. As discussed in an earlier section, establishing a fully integrated framework merging land-use and water resource management planning at a regional level might be considered the "gold standard" in terms of facing the challenges of drought and climate change. In the real world, planners can work toward such an ideal system while making the best of existing processes that are in place. That would involve increasing coordination and collaboration efforts on the part of both land-use and water management agencies.

If a local agency houses both land-use and water supply functions, it may be a bit easier to line up all the parties than it would be for local agencies with multiple water suppliers, or water suppliers with multiple local agencies in their jurisdiction. Nevertheless, efforts to bridge the gaps and eliminate overlaps can be very productive for both sides.

The first step for planners and water managers is to inform other agencies and stakeholders of their institutions' policies and planning processes. The next step is to become involved in the planning processes of other agencies. If formal agreements are not likely, establishing the roles and responsibilities of the involved parties informally at least can help to avoid problems later in the process.

If it is an option, building an in-house drought and climate action planning team can make the process easier. Planners can begin by involving other related departments or agencies within their own units of government. In addition to the planning department, which would most likely be in the lead position, and the climate action office, if one exists, there are a number of other departments that such a team might include. Table 3.2 lists potential in-house departments and agencies for land-use planning drought and climate action teams.

Water agencies can also work to build in-house drought and climate action planning teams. The first step a water supplier can take when developing a water shortage contingency plan is designating a team leader and members of an in-house water shortage team and identifying the roles and responsibilities of each. For smaller local water suppliers, this may be just one person. For larger local suppliers and wholesale water suppliers, an in-house team might include representation from a number of departments (Table 3.3).

The individuals on the action planning teams need to represent and have the authority to make decisions for their departments. The person selected to represent the water supplier for interagency committees should be cognizant of all functions and policies of the agency. The same is true for efforts initiated by the land-use agency.

While many of the activities associated with planning processes involve gathering and analyzing technical information, it is essential to involve and brief elected officials, mayors, supervisors, general managers, boards of directors, and others who make the political decisions that shape and implement the policies related to the planning process.

Once the team is assembled, the involvement of other stakeholders becomes important. Forming an interagency advisory committee to bring all potential partners to the table is best done at the beginning of the planning process. The inclusion of neighboring water districts and wholesale water suppliers can maximize resources and facilitate a regional approach. The opportunity for water transfers or water sharing during water shortages can be explored in advance through such a process.

Likewise, the formation of a community advisory committee can be a definite advantage. Community involvement is a cornerstone for the successful implementation of planning processes. Tables 3.4 and 3.5 (p. 42) list examples of potential interagency and community advisory committee participants.

COMMUNICATING DROUGHT TO THE COMMUNITY

A strong public culture of support for drought mitigation depends on early and constant involvement. The best way to build involvement is through a proactive outreach program aimed at key stakeholders. With such a culture in place, widely shared public discussion of mitigation priorities allows the community to preserve the best of its local character while simultaneously achieving effective drought mitigation.

To be most effective, the gold standard once again is to establish a regional, interagency public communications program. Most water shortage contingency plans, as part of urban water conservation plans in California, include a communication plan for drought times. Thus, a planning agency need not start from

TABLE 3.2. POTENTIAL IN-HOUSE LAND-USE PLANNING ACTION TEAM PARTICIPANTS

Building and zoning
Economic development
Emergency services
Environmental review
Fire
Information technology (IT) / geographic information systems (GIS)
Law enforcement
Legal
Mental health
Parks and recreation
Power utility
Public health
Public works
Social services
Solid waste
Sustainability unit
Water quality

TABLE 3.3. POTENTIAL IN-HOUSE WATER AGENCY ACTION TEAM PARTICIPANTS

Administrative
Communications
Conservation
Customer service
Environmental review
Finance
Flood management
General manager
Human resources
Information technology (IT) / geographic information systems (GIS)
Legal
Operations and maintenance
Planning and engineering
Stormwater management
Water treatment

TABLE 3.4. POTENTIAL INTERAGENCY ADVISORY COMMITTEE PARTICIPANTS

Emergency management agencies
Housing proponents
Neighboring land-use planners
Neighboring local water suppliers
Power utilities
Recycled water agencies
Regional associations of governments
Regional, state, and federal counterparts
Regional wastewater utilities
Research institutions
Transportation agencies
Watershed alliances

TABLE 3.5. POTENTIAL COMMUNITY ADVISORY COMMITTEE PARTICIPANTS

Agricultural interests
Building industry organizations
Commercial and industrial water users
Community-based organizations
Environmental organizations
General public
Homeowners associations
Landscape industry professionals
Mass media
Parks, schools, cemeteries, golf courses
Professional organizations
Tribes

scratch, but can partner with the water supplier to enhance or expand existing messages.

During water restrictions, publicity and communications have traditionally consisted of three main types: mass communication, targeted communication, and daily communication via agency websites and other media. Increasingly, electronic messaging through e-mail, text messages, website pages, Facebook, Twitter, and other social media platforms is becoming the bedrock of communication efforts.

Mass communications strategies include information posted on websites and through other electronic communications, articles in the local press, flyer inserts defining water restrictions, press releases, and legal notices. Paid advertising of all kinds as well as interviews on radio and TV programs are other communication avenues. In addition, utilities can take advantage of monthly bill mailings to send informational brochures and news to their customers. Targeted communications approaches include phone calls, meetings, group presentations, and in-person visits and correspondences.

Visual representations of water shortage impacts—such as color graphics depicting declining water levels, rainfall, and runoff, especially as compared to normal conditions—can be very effective tools to motivate users to adopt water conservation measures. Translating messages for citizens for whom English is a second language is critical in some communities.

Planning agencies and other stakeholders in the region can participate in the development of communications, link to pertinent messages, share electronic mail lists and other contact information, and include the information at their public meetings and events. Coordinating communication efforts at the regional level can help avoid conflicting public messages and can maximize limited financial resources.

In summary, planners and water managers across the nation are involved to a varying extent in planning for drought and climate change. By "sitting at each other's tables"—that is, becoming actively involved in each other's planning processes and ideally consolidating them at a regional level—communities can benefit from the improved economic, ecological, and social outcomes associated with establishing resilience to drought conditions.

CHAPTER 4

Drought Planning in Practice

Erin Musiol, AICP, with Nija Fountano and Andreas Safakas

The American Planning Association (APA) enlisted its partners in a search for exemplary case studies that highlight some of the most innovative and successful examples of water conservation and drought planning strategies underway today. Using a variety of criteria, including geography, scale, size and type of jurisdiction, context (rural, suburban, or urban), and applicability to a planning audience, the APA and its project partners chose eight case studies to highlight in this report. The case studies are presented in order of scale and complexity, and they range from efforts at the project or development level to national efforts to manage of one of the world's largest river systems.

Despite the differences in the case studies selected, several common themes or best management practices emerge. Communities looking to strengthen drought planning efforts should look for ways to adapt these ideas. Best management practices include:

- Establish a diverse committee (task force, board, group, etc.) representing a range of interests and charge it with providing direction on water- and drought-related issues; developing recommendations or policies related to water conservation and drought planning; drafting ordinances; leading community education and outreach efforts; and holding government officials accountable for implementing drought-related goals, policies, objectives, and action items.
- Undertake community education and outreach to ensure that the planning process is collaborative and transparent, all relevant stakeholders are at the table, and there is community buy-in.
- Develop regulations and modify existing regulations—including water conservation and irrigation ordinances, outdoor watering restrictions, and landscaping regulations—and require sustainability goals (like water conservation) in developer agreements, rezoning approvals, and performance standards.
- Create incentives, including rebate programs and credits on energy bills.
- Develop a stand-alone drought plan or include information on drought in existing plan documents (comprehensive plans, climate action plans, and hazard mitigation plans). The plans should include:
  * A community outreach process
  * Accountable implementation strategies with timelines
  * Consistency with other plans
  * A proactive approach to drought mitigation instead of a focus on drought response
  * Strategies to evaluate plan effectiveness and update the plan document
  * Strategies for managing water in the worst of droughts
- Create drought exercises to properly train relevant stakeholders and to offer a forum for information exchange, including suggestions for improving the drought-planning process.
- Undertake an integrated, cooperative approach to water supply management on a watershed or basin-wide level. This could be achieved formally through laws or agreements or more informally through established planning frameworks. In either case, the approach should:
  * Be in place prior to the onset of a drought
  * Include strategies that apply at various stages of drought
  * Ensure a consistent approach by all agencies involved
  * Establish a common set of triggers and actions
  * Require regular communication and open dialogue between stakeholders
- Share data and tools for monitoring, mitigating, and responding to drought with relevant stakeholders
- Diversify the water supply

- Undertake continuous data collection, forecasting, and monitoring that capture multiple variables, including population growth and climate change
- Update the drought plan on a regular basis

The following eight case studies illustrate how these best practices are specifically being utilized at the local, regional, state, and national levels.

CIVANO

Civano is a sustainable master planned community nestled south of the Catalina Mountains and west of the Rincon Mountains in southeast Tucson, Arizona. It is the first master planned community in the United States designed to balance natural resources with human needs. It incorporates sustainable planning principles in every facet of its design through the integration of passive and active solar principles, sustainable building materials, and water conservation technologies. The 818-acre community consists of four mixed-housing residential neighborhoods, community facilities, retail and employment uses, and dedicated open spaces.

This Civano house includes water-conservation design features such as xeriscaping and a water-harvesting system.

Simmons B. Buntin

A showcase of locally built solar-powered homes in 1981 sparked a vision for a new community in Arizona, one of reduced resource consumption minimizing adverse environmental impacts. A decade later, the newly formed Solar Village Corporation sculpted that vision into a development called the Tucson Solar Village. The Arizona State Land Department dedicated the land for the project and the City of Tuscon approved rezoning to allow for the master planned community (Buntin n.d.). The city broadened the conditions of the rezoning to include additional sustainability goals and performance requirements beyond solar. In addition to sustainability goals related to reducing home energy consumption and internal vehicle miles traveled, the project sought to reduce potable water consumption by 65 percent (Civano Neighbors Neighborhood Association 2009).

In 1995 the city adopted an Integrated Method of Performance and Cost Tracking (IMPACT) System for sustainable development that set standards and performance targets to help achieve the conditions established in the rezoning approval. These included:

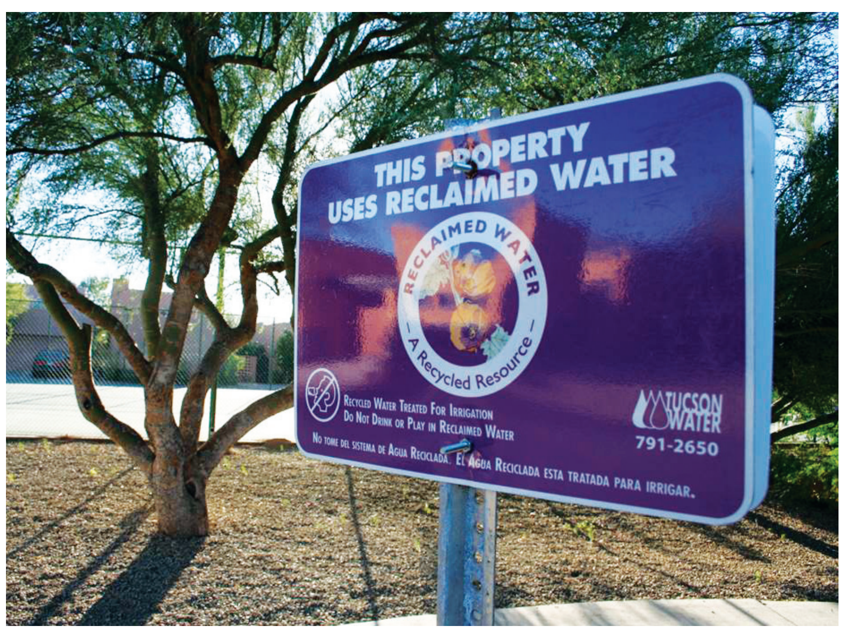
- Reducing interior residential potable water use to 53 gallons per person per day
- Reducing interior nonresidential potable water use to 15 gallons per employee per day

- Establishing a water budget per household of 28 gallons of water per person per day for exterior uses
- Discouraging the construction of private swimming pools (if installed, owners were required to install a pool cover and could only heat the pool using solar devices)

Other specific requirements included limiting site clearance for residential lots in order to preserve desert vegetation and maximize natural drainage; protecting important plant species and requiring that a significant portion of each building site maintain existing natural desert vegetation; applying city xeriscape landscape standards to all new developments; and requiring all landscape irrigation to be accomplished with nonpotable water through the use of reclaimed water, graywater systems, water harvesting systems, and other alternative irrigation systems (Tucson 2003).

With the IMPACT System in place, the city then sought out a master developer to undertake the project. In July 1996, a joint venture, the Community of Civano, purchased the property for $2.7 million with additional support provided by the city and private funders for infrastructure funding and energy designs; the Tuscon Solar Village was renamed Civano. The developer worked with consultants, universities, and community members to ensure that sustainable planning principles were incorporated into the final design.

The city entered into a memorandum of understanding (MOU) with the master developer in 1998 to guarantee that the standards would be implemented and the performance targets would be monitored. The master developer prepares an annual or biannual IMPACT System Monitoring Report to document the success of Civano in achieving the standards. The report includes a review of baselines, the methods for monitoring and establishing compliance, and the strategies and requirements appropriate to achieve compliance. Should the master developer for Civano discover a more effective or efficient way to achieve the performance standards, it can propose changes to the MOU. For example, the MOU was revised in 2003 when it was discovered that there was a substantial cost burden to homeowners for the use of separately metered reclaimed water at each home (Tucson 2003).



A reclaimed-water sign in the Civano community.

Simmons B. Buntin

According to the monitoring reports, Civano has been successful in reducing potable water usage well below the minimum baseline. In 2006 water use in Civano was 55 percent lower than the average city usage (Al Nichols Engineering 2009). A 2008 report found that in 2007 the Civano I neighborhood used approximately 59 percent less potable water and the Sierra Morado neighborhood used approximately 37 percent less potable water than the typical Tucson home (Witmer 2008).

Conclusion

Civano serves as a model of how to remarkably reduce potable water usage at the development level. By incorporating sustainability goals into the rezoning approval process and developing an IMPACT System to ensure the standards and performance targets are implementable and measurable, the community has drastically reduced its water usage as compared to the rest of the city. Through regular monitoring and evaluation, the community can also continually improve the strategies it employs to meet established standards. Other communities should look to this development when exploring effective water-conservation strategies and technologies at the project level.

HUALAPAI TRIBE

The Hualapai Reservation is located in northwestern Arizona and covers nearly one million acres of land, including 108 miles along the Colorado River and the Grand Canyon. Peach Springs, located at the southern boundary of the reservation, is the tribal headquarters location and where the majority of tribal members reside. In total, about 2,000 individuals live on the reservation (Christensen 2003).

Like most tribes in the United States, the Hualapai live in a drought-prone region of the United States and have experienced periodic droughts throughout history. In recent years, lengthy periods of drought and extreme drought conditions, coupled with rapid population growth and competition for water, have left the reservation (and the larger region) increasingly water stressed. In late 2002, the Hualapai began developing a Cooperative Drought Contingency Plan to help them better understand the physical characteristics of drought, investigate their drought vulnerabilities, and identify actions that can be implemented before and during drought to help minimize its effects (Christensen 2003).

The plan, funded by a cooperative agreement with the U.S. Department of Interior's Bureau of Reclamation (BOR), was developed entirely by members of the tribe. The plan took a little over a year to develop and was adopted in December 2003. In 2004 it became the first tribal drought plan to be accepted by Congress through the BOR's Lower Colorado Region (Christensen 2003).

Plan Development

A lead planner first undertook the process of developing the plan but soon realized that a collaborative effort was necessary to gain a broader understanding of potential drought mitigation and response measures appropriate for the reservation. As a result, the Hualapai Tribal Council created the Hualapai Drought Task Force (HDTF). The HDTF includes the water resources program manager; the Bureau of Indian Affairs fire management officer; the wildlife, fisheries, and parks program manager; the agriculture program manager; the air quality program manager; a tribal elder; the assistant agriculture program manager; and willing presidents of the livestock associations (Christensen 2003). Initially the HDTF met twice monthly, but this increased to twice-weekly meetings during the last two months of plan development (Christensen 2013).

Throughout the planning process, the Hualapai held several meetings with the community and tribal officials to inform tribal members of the need for a planning process, gain feedback on the document, address contentious issues, and foster buy-in for the project. Tribal members agreed that the planning process was transparent and collaborative and that it resulted in a plan that met most members' needs.

According to Dr. Kerry Christensen, senior scientist with the Hualapai Tribe Department of Natural Resources, the task force was integral in bringing people from different agencies together to discuss what they were doing to plan for and respond to drought and what they could do moving forward. He also said that, although the tribe has always been in tune with the environment, the planning process for the drought plan was necessary to develop widespread recognition of the seriousness of the issue (Christensen 2013).

Plan Content

The Cooperative Drought Contingency Plan provides information on the physical and social characteristics of the reservation, highlighting the sectors that are most vulnerable to the effects of drought. The plan then outlines a drought monitoring protocol that is to be used in assessing drought and activating drought response stages. Next, the plan outlines mitigation and response actions and assigns a responsible party for ensuring each action is carried out. Finally, the drought plan identifies short- and long-term capital improvement projects that are needed to reduce the tribe's vulnerability to future drought (Knutson et al. 2007).

The plan identifies all the programs, departments, agencies, and entities—internal and external—involved with preparation for and response to drought on the Hualapai Reservation. It assigns them specific activities to oversee during every stage of drought. The Hualapai Tribal Council directs the participation of internal Hualapai departments and programs around activities identified in the plan. Additionally, the Hualapai ensured that all of the activities assigned to outside agencies were consistent with the agencies' missions so they would have the authority to provide technical assistance and funding sources. The plan also moves beyond drought response activities focused on drought relief to emphasizing drought mitigation activities that can be done at all stages of drought and reduce the likelihood of harm from future drought events.

The plan states that it will be reviewed and amended as needed every two years and that the HDTF will meet annually to discuss the plan.

Plan Implementation

The key principle behind long-lived and influential plans is accountable implementation (Godschalk and Anderson 2012). No matter how well-written or strong the planning process, a plan that ends up gathering dust on the shelf is not going to produce the outcomes the community desires.

According to Christensen, everything in the drought contingency plan is being implemented. The Hualapai successfully sought funding from the BOR for emergency drought relief and have been able to undertake several activities and projects, including developing water storage, drilling new wells, hauling water, replacing pipeline, and increasing water supply. They have also increased their coordination and cooperation with outside agencies like the U.S. Department of Agriculture's Natural Resource Conservation Service, with which they are working to improve range conditions. Additionally, they have increased drought monitoring efforts, reviewing Palmer Drought Severity Index and Standard Precipitation Index data available from the National Drought Mitigation Center (NDMC) and the National Climatic Data Center on a weekly basis (Christensen 2013).

Drought has the potential to limit, or even suspend, rafting trips on the Colorado River, an important source of revenue for the Hualapai Tribe.

Cody Knutson

The Hualapai are currently establishing a GIS/GPS database of all water-related infrastructure on the reservation (wells, tanks, pipes, etc.) to better understand the system and how to improve it. The Hualapai Tribe Department of Natural Resources is also currently developing watershed management plans for each of the reservation's nine watersheds (four of which have been completed) to improve water availability on the reservation (Christensen 2013).

Plan Evaluation

Not only have the Hualapai served as a model for accountable implementation of the plan activities and projects, they have also undertaken a thorough evaluation of the effectiveness of the plan. They granted the NDMC permission to conduct a drought exercise on the reservation in October 2005. Tribal and federal representatives were asked to discuss recent drought impacts on the reservation, review their respective mitigation and response obligations outlined in the plan, and comment on the usefulness and relevancy of the obligations for reducing impacts. They were also taken through a range of potential drought scenarios to gauge the level of understanding with proper response protocol.

The drought exercise was helpful in educating new tribal representatives on their roles and responsibilities before and during times of drought. It also yielded information on barriers to be addressed to fully implement the plan, provided recommendations to improve the plan, and outlined lessons learned (Knutson et al. 2007).

The Hualapai were also one of several tribes that participated in a drought planning workshop organized and facilitated by the NDMC and sponsored by the BOR in June 2004 to discuss the progress of tribal drought planning in the region. Representatives from 11 tribes presented their drought planning activities and discussed successes, barriers, lessons learned, and changes they were contemplating making to their drought plans (Ferguson et al. 2011).

One area for potential improvement relates to plan accountability. Although the plan states that it will be reviewed and amended biannually and that it will be discussed by the task force on an annual basis, Christensen indicated that the plan has not been reviewed nor is the task force conducting formal meetings. Also, the recommendations that came out of the drought exercise have not been incorporated into the plan. Continuing to discuss the plan and improve its content will only help to improve the Hualapai's ability to mitigate and respond to future droughts.

Conclusion

Although tribes face different cultural, political, and technical issues when planning for and dealing with drought conditions, other reservations as well as nonreservation communities can learn from the Hualapai drought contingency plan and planning process (Knutson et al. 2007). The Hualapai had a collaborative, transparent planning process that brought all the appropriate stakeholders to the table and fostered community buy-in. The plan identified activities and assigned responsibilities, but most importantly it went beyond responding to drought to proactive mitigation of the effects of future droughts. Lastly, the tribe did not stop after the plan was adopted. It immediately began to implement the activities set forth in the plan, and implementation of plan activities continues to this day. The Hualapai have internally evaluated the effectiveness of the plan and have openly received input and comments on the plan from other tribes and agencies.

ATHENS-CLARKE COUNTY, GEORGIA

Athens-Clarke County (ACC), Georgia, is located 65 miles northeast of Atlanta. At approximately 122 square miles, it is the smallest of Georgia's 159 counties; however, it is the 18th most populous and also home to the University of Georgia. According to the U.S. Census, the 2010 population of the county was 116,714.

Drought and Water Planning

A prolonged drought in Georgia in the mid-1980s left the piedmont region of Northeast Georgia (Athens-Clarke, Barrow, Jackson, and Oconee Counties) facing limited surface water and groundwater supplies. Concerned about an economical and reliable water source, the counties, along with the Northeast Georgia Regional Development Center, formed the Upper Oconee Basin Group (UOBG) in 1987 to research water resources in Northeast Georgia (UOBWA n.d.).

Athens-Clarke County, Georgia, is dependent on the Middle Oconee and North Oconee Rivers for its drinking water supply. The water intake on the Middle Oconee River has ranged from normal river flows (above) to significantly lower flows during the drought of 2007 (right).

Athens-Clarke County Water Conservation Office

The UOBG findings revealed the need to acquire and develop adequate sources of water supply for the region. In 1994 the counties comprising the UOBG adopted local resolutions approving the passage of state legislation to create the Upper Oconee Basin Water Authority (UOBWA), which was charged with leading this effort. The member counties decided it was in their collective best interest to purchase water from a regional reservoir owned and controlled by the authority. In return, the authority is obligated to deliver an allocation of water to each member county as agreed upon in the act (UOBWA n.d.).

The authority focused its efforts on the development of the Bear Creek Reservoir and associated pump station and the construction of the Bear Creek Water Treatment Plant. The regional reservoir was completed and dedicated in 2002. Drought problems continued, and by August 2002 the new reservoir was already down to 67 percent of its total volume and water use in Athens was higher than it had ever been. Although Georgia had statewide water restrictions in place at the time, the UOBWA and ACC approved more stringent restrictions prohibiting all outdoor watering seven days a week, 24 hours a day (Hall 2013a). Public utility staff also began work on a proposal to implement a conservation rate structure.

Little community outreach was done prior to county commission approval of the restrictions. ACC had no drought plan or documented drought response measures in place and no preemptive drought public outreach strategies. As a result, the community found the restrictions to be arbitrary and unnecessary, and they were not well received (Hall 2013a).

Those in the ornamental industry—including professional landscapers, lawn service companies, and garden center and greenhouse owners—were particularly affected by the ban and in strict opposition to the rate structure under development. In September 2002, they organized to form the Bear Creek Urban Agriculture Group (BCUAG) with the goal of convincing the mayor and commission to prevent future outdoor watering bans and curtail efforts to implement additional water conservation measures such as conservation pricing (Pearson and Thomas 2006).

The BCUAG was motivated and well organized. Within weeks the group's members accomplished the following:

- They worked with University of Georgia (UGA) Cooperative Extension Service agricultural economists to determine economic impacts associated with the ban.
- They obtained data from the Department of Agriculture about the number of horticultural businesses licensed in the area, the overall annual sales values, employment figures, and tax contributions.
- They developed a series of talking points and press releases.
- They elected leaders to speak on their behalf.
- They established a phone network to spread timely communications and updates.
- They met with commissioners, business leaders, and state representatives and contacted neighboring county commissioners, keeping them informed of evolving organizational plans.
- They requested input from industry experts, including the Georgia Green Industry Association and landscape industry conservation consultants.
- They wrote letters to the editor and approached newspapers, radio, and TV to get the word out about their stance on the issues (Pearson and Thomas 2006).

Five weeks after the BCUAG was formed, the group attended a commission meeting to petition the mayor and commissioners to remove the ban and to express its concerns over the rate structure under development. Luckily for the BCUAG, the drought was easing so the commissioners had already planned to lift the ban (Hall 2013a). Although the ban could be lifted, ACC realized the treatment plant and water supply source could not handle the summer peak of local water usage. It also became clear that a rate structure was a contentious issue. The commissioners recognized that ACC needed to develop a long-term plan to address drought and water supply issues in the county (Hall 2013a).

In June 2003, six months after modifying the ban, the mayor appointed a Water Conservation Committee (WCC) to assist in identifying and developing cost-effective water conservation and demand-management alternatives, general and site-specific conservation programs, and other water efficiency measures. The WCC comprised 14 members and three technical advisors, including UGA faculty, landscapers, and ACC officials and staff. Representatives from the BCUAG were also appointed to the committee (Hall 2011).

The WCC was charged with the following objectives:

- Devise a series of community water conservation steps that would reduce everyday water wasting in the community.
- Devise an outdoor watering ordinance that would be reasonable and fair and not eliminate the green industry.
- Devise a drought management plan that fairly distributed the pain across all industries and homeowners rather than singling out a few, such as nurseries.
- Devise a water conservation rate structure that would encourage citizens to save water during the summer months.

In addition to the objectives directed by the mayor, the UOBWA set the goal of reducing average per-capita water use by 17.5 percent by 2050 for all of the authority's members. The WCC was responsible for developing the strategies to accomplish this goal in ACC. They also established additional goals of reducing peak water usage to extend ACC's system capacity and allow Athens to extend the Bear Creek supply to 2040 and the water plant to 2050 (Pearson and Thomas 2006).

As soon as the members were appointed, the WCC began meeting regularly and formed active subcommittees. Over the course of six years, they were able to accomplish all of the items for which they had been tasked as well as many others. Most importantly, they were able to improve relationships between the county and industry, the green industry in particular. A new mayor elected in 2010 chose not to reappoint the committee. However, in its few years of existence, the WCC managed to establish a lasting legacy in the Water Conservation Office (Hall 2013a).

Water Conservation Ordinances

In a strategic move, the WCC developed three water conservation ordinances, from least controversial to most controversial. The first ordinance, Water Conservation, was adopted in 2004. The second, the Drought/Water Shortage Management Plan (DWSMP), was adopted in 2007. The third, the Conservation Rate Structure, was adopted in 2008.

This approach proved critical in gaining the momentum necessary to develop the conservation rate structure—the most controversial measure of the ordinance. The WCC had earned respect through the process of developing and approving the previous sections of the ordinance; when it was time to introduce the rate structure for approval, it was well received (Hall 2013a).

Water Conservation Ordinance. In April 2004, ACC adopted the Water Conservation Ordinance (ACC 2004). This ordinance exceeds most water conservation ordinances because it includes a 24/7, 365-day water conservation plan with full-time water restrictions. It stresses that water conservation is something that should be done on a daily basis and not just in times of drought or water shortage. The ordinance establishes a permanent outdoor watering schedule, prohibits certain uses that have been defined as wasting water, and imposes surcharges on those who violate the ordinance (ACC 2004).

Drought/Water Shortage Management Plan. ACC, as a part of the authority, is subject to the regulations set forth in the Oconee Basin Water Authority Drought Contingency Plan adopted in 2005. This plan determines the percentage water-use reduction goal and the penalty for nonattainment (UOBWA 2005).

However, ACC has no wells to use as backup supply, it is more urbanized than other cities and counties in the authority, and it was very close to running out of water. Therefore, ACC adopted a more detailed Drought/Water Shortage Management Plan (DWSMP). The plan describes the strategies the county will use to meet the goals set forth in the UOBWA Drought Contingency Plan. Before this plan was created, it was up to the public utilities director to determine the drought response strategy. Writing the strategies into the plan allows residents to see exactly what the community can expect in case of a drought, eliminating the uncertainty and unpredictability of past strategies (ACC 2007).

The DWSMP prioritizes the uses of potable water that can be drawn from the water system during periods of water shortage. It also sets drought and water shortage management measures for water usage that are broken down into six steps, A through F, that range from specifying even and odd days for spray irrigation and drip or hand watering (Step A) to a total ban on outdoor water use (Step F). The DWSMP also establishes indicators (both primary and secondary) and triggers for determining when ACC is in a drought (ACC 2007).

In 2010, due to the frequency and longevity of droughts experienced in the state of Georgia, the state passed the Water Stewardship Act. The act required the adoption of water restrictions in local ordinances as well as revisions to state water-related policies and regulations (GDNR et al. 2010). ACC's DWSMP was (and still is) more stringent than state requirements. As part of the UOBWA, it regularly petitions the state for the ability to use its more stringent management plan in times of extreme drought (Hall 2013a).

Conservation Rate Structure. The WCC developed a four-tiered rate structure for residential water and sewer rates. Rates are based on a four-month winter average (WA) when water demand is at its lowest. The base rate, Tier 1, applies to water use up to each customer's WA. Users are charged a higher rate for additional water use up to 10 percent over the WA (Tier 2), more than 10 to 25 percent over the WA (Tier 3), and more than 25 percent over the WA (Tier 4). This rate structure, implemented on July 1, 2008, has helped to curb water wasting and excessive water use in the county (ACC 2004).

Although the green industry was originally strongly opposed to the idea of a rate structure, the WCC was able to develop a structure that was agreeable to all members—including green industry representatives. According to Marilyn Hall, water conservation coordinator with the Water Conservation Office, the green industry representatives actually proved instrumental in getting the rate structure approved, which highlights the importance of having all stakeholders at the table throughout the planning process (Hall 2013a).

Irrigation Ordinance

The WCC was also in the process of developing an Irrigation Ordinance when the decision not to reappoint the committee was made. The ordinance includes policies that encourage drip irrigation systems and require rain gauge or soil moisture cut-offs for automated sprinkler systems. It also establishes design and construction standards for irrigation systems and certification requirements for irrigation installation contractors. Finally, the ordinance requires all in-ground irrigation systems to have permits and be metered (Hall 2013b).

Because ACC has reached its water use goals, the urgency for such an ordinance has diminished. However, it may be needed in the future, and the framework for the ordinance is largely in place.

Water Conservation Program

ACC also manages a Water Conservation Program that handles water-related education and public awareness in the county. The program began in 1995, with the hiring of the county's first water conservation coordinator. In 2005 ACC created the Water Conservation Office under the Public Utilities Department to oversee the Water Conservation Program (Hall 2013a). The program consists of family events, speeches at schools and teacher workshops, tours of the water treatment plant, xeriscaping demonstrations, water audits, water conservation programs, and water conservation awards and best management practices for outdoor landscape water use (ACC 2013).

The WCC is responsible for the size, power, autonomy, and community acceptance of the Water Conservation Office and Program. Over time the commission has approved enhancements to the program, like funding for a water conservation education specialist and graduate assistant, in response to direct recommendations made by the WCC (Hall 2013a).

The WCC also strengthened the education and outreach roles of the Water Conservation Office. It arranged for preemptive public outreach to notify residents when a drought is likely. The WCC conducts regular radio interviews, sends a quarterly newsletter to every customer, and holds public events on a regular basis, not just during water shortages.

Kathy Hoard, ACC commissioner, said that when the WCC first began its education and outreach efforts, "the community wasn't aware of just how bad conditions were." Representatives spoke at events and community meetings and met with special interest groups. In her opinion, one of the WCC's greatest accomplishments was the strong relationship it formed with the commercial and industrial sectors through a commercial/industrial subcommittee that met with the county's top 25 water users to discuss ways to conserve water. Members of the WCC and the commercial sector sponsored an expo at the civic center in town. A diverse mix of interests showed up at the event: companies, business owners, and even a representative from the local homeless shelter—all interested in learning about ways to save money and water. The event did not cost the county a penny, and raised awareness about the severity of the issue. Hoard called it "a win-win for everybody" (Hoard 2013).

Conclusion

ACC is an example of how a group of motivated and concerned citizens were able to come together to initiate change in the way water planning was done in the county. Prior to its efforts, the county was reacting to drought, forced to impose stringent bans on water use once situations had become dire. Unhappy with the outcomes that resulted from these types of decisions, the BCUAG group organized—collecting data, networking, developing marketing materials, and getting its message heard. Instead of disbanding after small victories, the citizens pushed the county to develop long-term and transparent solutions for water conservation. As a result of the BCUAG's efforts, ACC created a formal committee, the WCC, to address water conservation issues, and the group got a seat at the table. The WCC has achieved several victories, including development of a Water Conservation Ordinance, Drought/Water Shortage Management Plan, and Conservation Rate Structure, as well as education and outreach through its involvement in the Water Conservation Program. These efforts have played a significant role in reducing water consumption in the county with 2012 average daily water use less than the usage in 1989.

ALBUQUERQUE, NEW MEXICO

Albuquerque is the largest city in New Mexico, with a 2011 population of 552,804. It is located in the central part of the state, straddling the Rio Grande. It has a dry and semi-arid climate, with plenty of sunshine and little rainfall.

Albuquerque relies on two sources for its drinking water: groundwater from the Santa Fe Group aquifer and San Juan-Chama surface water diverted from the Rio Grande. The Santa Fe Group aquifer was readily recharged by groundwater from the Rio Grande, and as a result, the city believed its water resources to be virtually limitless. With little concern about future water supply, water conservation was not a priority. Residential and commercial property owners excessively watered lawns and landscaping, using billions of gallons of water annually. This problem was exacerbated with the housing boom in the 1990s, as the number of homes with lawns grew substantially. Turfgrass, a non-native species in New Mexico, requires large quantities of water to survive. By 1995 per-capita water use in the city had reached 251 gallons per day (Albuquerque 2004).

In 1993 the U.S. Geological Survey (USGS) published a study revealing that the aquifer was nowhere near the size it once appeared to be and was being pumped out faster than rainfall and snowmelt could replenish it (Royte 2010). In fact, the rate of groundwater withdrawals by the city was more than twice the amount that could be sustained over time (Kaminski 2004). The study also revealed that drilling deeper for water would likely result in a reduction in water quality and that alternative plans to divert surface water from the Colorado River basin were not feasible. Based on these conclusions, the city recognized a need to reassess its current and future water needs (Kaminski 2004).

In 1994, with the help of hydrologists and engineers, the city began establishing a Long-Range Water Conservation Strategy (LRWCS) (Yuhas 2013). The LRWCS included an aggressive water conservation program and policies to make more direct use of surface water supplies and to reclaim wastewater and shallow groundwater for irrigation and other nonpotable uses (Kaminski 2004). Finally, the LRWCS included a goal of reducing per-capita water use by 30 percent by 2004 (Kaminski 2004).

Using the LRWCS as a framework, the city adopted a Water Conservation Landscaping and Water Waste Ordinance in 1995. The ordinance includes the banning of turf installation for new commercial developments, the removal of turf on slopes with a grade greater than 17 percent and no less than 10 feet in any dimension, and a rebate program for turf removal from residential and commercial properties. The rebate program, which has had 6,264 participants since 1997, offers property owners $1 per square foot or $1.50 for slopes if they replace their turfgrass with more resilient native vegetation like shrubs, wildflowers, and wild grasses (Yuhas 2013; Albuquerque 2013).

The Water Utility Authority (WUA), which led the city's water reduction efforts, realized that public education and outreach were critical to getting people to reduce their water usage. Over the year-and-a-half period when the LRWCS and Water Conservation Landscaping and Water Waste Ordinance were being developed, the WUA sponsored public meetings to gauge the public's understanding of water conservation and offered a forum to express concerns. The public was also involved in establishing the water reduction goal set forth in the LRWCS.

To help the city meet its water reduction goal, the WUA developed a how-to guide for property owners choosing appropriate landscaping for their properties. The guide, completed in 1996, features a wide variety of alternatives to turfgrass and includes data on sunlight exposure and water needs (Albuquerque Bernalillo County WUA 2013). The WUA also began sponsoring an hour-long seminar on irrigation efficiency that provided customers with a $20 credit on their next utility bill. This seminar is still offered today. According to the WUA, customers who participated in the seminar achieved an 18 percent reduction in water usage (Yuhas 2013).

Albuquerque has continuously surpassed its water reduction goals since it adopted the LRWCS. The original goal, set in 1995, was to reduce per-capita water usage from 250 gallons per day to 175 gallons by 2005, but by 2005 Albuquerque had reduced water usage even further to 172 gallons. In 2006 a new goal was set of 150 gallons per person per day by 2014, which the city exceeded in 2011 at 148 gallons per person per day (Yuhas 2013). From 1995 to 2012, Albuquerque reduced its outdoor water usage from 42 percent of total water usage to 37 percent despite an increase in population of approximately 30 percent (Yuhas 2013). The city set a new goal in 2013 of a per-capita daily water-usage rate of 135 gallons to be reached by 2024.

TAMPA BAY WATER

Tampa Bay Water (TBW), a nonprofit special district of the state of Florida, is the largest regional water supply authority in the state. It provides wholesale potable water to 2.3 million customers in three counties (Hillsborough, Pinellas, and Pasco) within the Tampa Bay region.

The Tampa Bay region is located in the west-central portion of the state and has traditionally relied on the Floridian aquifer for the bulk of its water supply. The region has distinct wet and dry seasons, making it susceptible to both drought and flooding. This variation in rainfall creates continuous challenges in managing the region's water supplies.

History of Water Policy

Early Florida water law was based in custom and case law, meaning it operated on a case-by-case basis rather than in a comprehensive manner. Even before Florida experienced rapid urbanization and population growth, this common-law approach prevented landowners from managing water resources with a forward-looking view (Carriker and Borisova 2009).

During the 1950s and 1960s, Frank Maloney, a professor and later dean of the University of Florida College of Law, published a series of law journal articles that presented extensive research and analyses about Florida case law pertaining to surface water, groundwater, diffused surface water, and water pollution. He found deficiencies in the common-law dispute settlement process for water management in Florida's environment of rapid population and industrial growth. The capstone of Maloney's work (in collaboration with several of his colleagues), *A Model Water Code*, was published in 1970 (Carriker and Borisova 2009).

Rapid population growth in the 1950s threatened the region's water supply. Local governments were competing for the same limited groundwater resources. Many sites were experiencing overpumping, and new water supplies were not being developed at the pace needed to sustain future demands. Policy makers and water managers began to argue for more cohesive policies that addressed water quality and quantity problems and a more integrated regulatory structure at the state level. In 1972, during one of Florida's periodic extended droughts, the Florida legislature met to address growing concerns about deficiencies in the institutional mechanisms for water management. The legislature enacted the Florida Water Resources Act of 1972, largely based on *A Model Water Code* (Carriker and Borisova 2009).

Pursuant to provisions in the Florida Water Resources Act, the state was divided into five water management districts. The Tampa Bay region falls under the Southwest Florida Water Management District (SWFWMD). At this time, the regulatory program of the pre-existing SWFWMD was expanded from flood control to more broad-based water resources management.

In January 1974, the state enacted its first major amendment to the Water Resources Act, which enabled local governments to engage in regional water supply planning. Through this provision, Hillsborough, Pinellas, and Pasco Counties and the Cities of St. Petersburg and Tampa signed the first interlocal regional water supply agreement in the state, establishing the West Coast Regional Water Supply Authority. The authority was established to help resolve longstanding disputes among communities of the Tampa Bay region, including who should operate the wellfields, which sources should be shared between governments, and what to do about overpumping at some sites, which was causing environmental impacts and saltwater intrusion into the aquifer (West Coast Regional Supply Authority 1978).

Overpumping continued for more than a decade and disputes remained unresolved, culminating in all-out water wars among the Tampa Bay region's governments. The SWFWMD imposed special requirements for existing water users and permit applications in portions of Hillsborough, Pinellas, and Pasco counties in order to reduce levels of pumping. In 1991 the SWFWMD created the Northern Tampa Bay Water Use Caution Area (WUCA), which further modified wellfield pumping levels (Florida Department of State 2010).

The region's governments recognized the need to develop new water sources to resolve disputes, address environmental impacts, and meet anticipated future shortfalls. The SWFWMD created an innovative financial assistance mechanism to accelerate the development of alternative water sources. The New Water Source Initiative (NWSI), established in 1993, provided significant financial assistance to water supply planning projects that had positive environmental impacts, were collaborative in nature, and would enhance long-term water supply (SWFWMD 2001).

Despite these efforts, escalating legislative and legal battles continued through the late 1990s. Conflicts between water regulators, water suppliers, environmental advocates, and property owners were aired in administrative hearings and court systems without resolution (SWFWMD 2010).

In 1997, under the leadership of a new board president, the SWFMWD and Tampa Bay area governments began meeting regularly, setting the foundation for a cooperative resolution. On May 27, 1998, after many months of negotiations, the parties entered into a partnership agreement. The agreement reorganized the West Coast Regional Water Supply Authority as Tampa Bay Water (TBW) and the SWFWMD committed $183 million in matching funds for the development of alternative water supplies to achieve a reduction in wellfield pumpage. TBW expanded to include the City of New Port Richey along with the existing member governments of the West Coast Regional Water Supply Authority. The partnership agreement ended nearly 25 years of water management conflict in the Tampa Bay region.

Under the partnership agreement, TBW was required to develop a master water plan. The plan identified new alternative water sources and described potential projects to meet future water supply needs. Many of these projects were eligible for funding through the NWSI and subsequent district funding programs. The agreement also called for increased water conservation and reclaimed water use by the member governments.

Diversifying the Water Supply

TBW quickly began to implement the recommendations set forth in the master water plan to diversify the region's water supply. The Enhanced Surface Water System (ESWS) was the first alternative water supply project implemented, which included three surface water sources (the Tampa Bypass Canal and the Hillsborough and Alafia Rivers), a large surface water treatment plant, and a 15.5-billion-gallon off-stream storage reservoir. The surface water treatment plant was completed in 2002, providing TBW's first alternative water supply source to groundwater. The ESWS is designed to capture and treat rainfall before it is lost from the system. Excess water captured is either treated and delivered to local distribution systems or stored in the C.W. Bill Young Regional Reservoir, which was completed in 2005, for future treatment and use (Figure 4.1). The reservoir is used to supply the water treatment plant during dry times. Because of the region's special hydrological conditions, with wet and dry cycles, this storage capacity is critical to the success of the ESWS (Frahm 2013). Withdrawals are based on available river flows to protect both low and high flows and no water is withdrawn below a designated low-flow amount (TBW 2013b).

Figure 4.1. *During the rainy season, excess water from the Tampa Bypass Canal and the Alafia and Hillsborough Rivers is sent to the C.W. Bill Young Regional Reservoir. This water helps bridge the gap during the dry season.*

Tampa Bay Water

In 2007 TBW completed a seawater desalination facility, adding a third source of water supply to the region (Figure 4.2). The desalination facility is the largest in the United States, with a plant capacity of 25 mgd (millions of gallons per day) of drinking water, compared with the approximately 250 other desalination plants operating in the United States with average plant capacities of less than 0.025 mgd (Tinker 2006). It is also the only seawater desalination plant; other plants treat brackish groundwater. The desalinated seawater is blended with treated water from other supplies before being delivered to customers. TBW considers the desalination plant to be a critical third water source because it does not rely on rainfall levels like groundwater and surface water—making it drought proof (TBW 2013c).

Figure 4.2. *The Tampa Bay Seawater Desalination Plant provides up to 25 million gallons of drinking water per day—an important drought-proof, alternative water supply for the region.*

Tampa Bay Water

Although TBW has diversified the region's water supply, groundwater from the Floridian aquifer remains an important part of the water supply system. During the negotiations that led to the creation of the partnership agreement, member governments transferred ownership and control of all regional wellfields in the Tampa Bay area, resulting in a single consolidated permit for those 11 wellfields (the TBW operates two other regional wellfields that are geographically separated from the consolidated wellfields). The new permit has a lower annual average pumping limit than what was previously permitted. Through consolidating permits and lowering the annual average pumping limit, TBW can ensure higher groundwater levels and promote environmental recovery in area lakes and wetlands (TBW 2013a).

Currently, TBW is the only utility in the United States that takes advantage of three sources for its water supply (TBW 2013b). Source distribution levels vary monthly based on a number of climate and hydrological variables; however, according to TBW year-to-date calculations, about 67.3 percent of the region's water supply is groundwater, 24.4 percent is surface water, and 8.3 percent is desalinated water (TBW 2013c).

Water Shortage Mitigation Plan

The Tampa Bay region's distinct hydrological conditions make it susceptible to periodic water shortages and drought. In 2001 the region (and the state as a whole) was experiencing the worst drought on record. TBW responded by developing a Water Shortage Mitigation Plan (WSMP). The purpose of the WSMP is to provide TBW and its member governments a strategy for identifying and responding to water supply shortages caused by hydrologic drought conditions (TBW 2009). The plan has had multiple updates as needed, most recently in 2009.

The plan defines four phases of water shortage with hydrologic- and supply-based triggers for determining entry and exit conditions for each defined water shortage phase. These phases are concurrent with the SWFWMD Water Shortage Plan phases; however, they are more specific to local supply circumstances. Recommended actions for supply management and potential demand reduction, as well as public and agency communications strategies, are included in the plan to minimize the impacts of water shortage in areas served by TBW member governments.

The plan also includes strategies for ensuring consistency with water shortage strategies undertaken by the SWFWMD and member governments. TBW and member governments must at a minimum comply with water shortage provisions issued by the SWFWMD. Either entity can choose to implement more restrictive provisions or equally restrictive but different provisions that are more sensitive to local contexts.

Conclusions and Lessons Learned

Diversifying the region's water supply, and subsequently reducing groundwater withdrawals, has had many positive effects in the region beyond increasing water supply. The water levels in the region's wetlands and water bodies have increased and aquifer levels have increased an average of 6.2 feet (TBW 2013c). Additionally, the diversified water supply has helped TBW meet increased demands and has improved reliability of the region's variable water supply, especially in times of water shortages.

TBW continues to work closely with the SWFWMD and member governments on water planning, water source protection, and water conservation. Representatives from TBW and member governments meet monthly to discuss water conservation planning issues and also coordinate regularly on permitting and other issues. This coordination provides for meaningful collaboration and innovation after decades of conflict and impasse. The partnership agreement creating TBW provided an innovative, regional framework for managing a regional water supply network and serves as a model for other regions facing water supply and environmental challenges.

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

The Potomac River, the primary source of water for the Washington, D.C., metropolitan area (WMA), provides about 75 percent of the area's water. The drainage area of the Potomac is slightly under 15,000 square miles in four states (Maryland, Pennsylvania, Virginia, and West Virginia) and the District of Columbia (Figure 4.3). The population in the basin is approximately 6.1 million, with 5.4 million residing in the WMA (ICPRB 2012e). The three largest water utilities in the WMA include the Washington Aqueduct Division of the U.S. Army Corps of Engineers (USACE), the Fairfax County Water Authority, and the Washington Suburban Sanitation Commission (WSSC).

The Interstate Commission on the Potomac River Basin (ICPRB) is a nonregulatory agency that provides leadership around water management in the Potomac River basin. It was created with an interstate compact by an Act of Congress in 1940, making it one of the first organizations with a congressional mandate to consider water resources on a watershed basis. It is composed of commissioners representing the federal government; the states of Maryland, Pennsylvania, Virginia, and West Virginia; and the District of Columbia. The ICPRB's mission is to enhance, protect, and conserve the water and associated land resources of the Potomac River basin and its tributaries through regional and interstate cooperation (ICPRB 2012a).

Under the original law, the ICPRB was focused on pollution abatement and the control of future pollution of interstate streams. An amendment to the ICPRB Compact in 1970 included other water problems such as water quantity. The compact recognized that "regulation, control, and prevention of pollution is directly affected by the quantities of water in said streams and the uses to which such water may be put" (ICPRB 2012f). The compact allowed for more integrated and coordinated planning in the development and use of the water and associated land resources in the basin (ICPRB 2012f).

The ICPRB Section for Cooperative Water Supply Operations on the Potomac River (CO-OP), created in 1979, is a special section of the commission that functions as a technical operations center for management

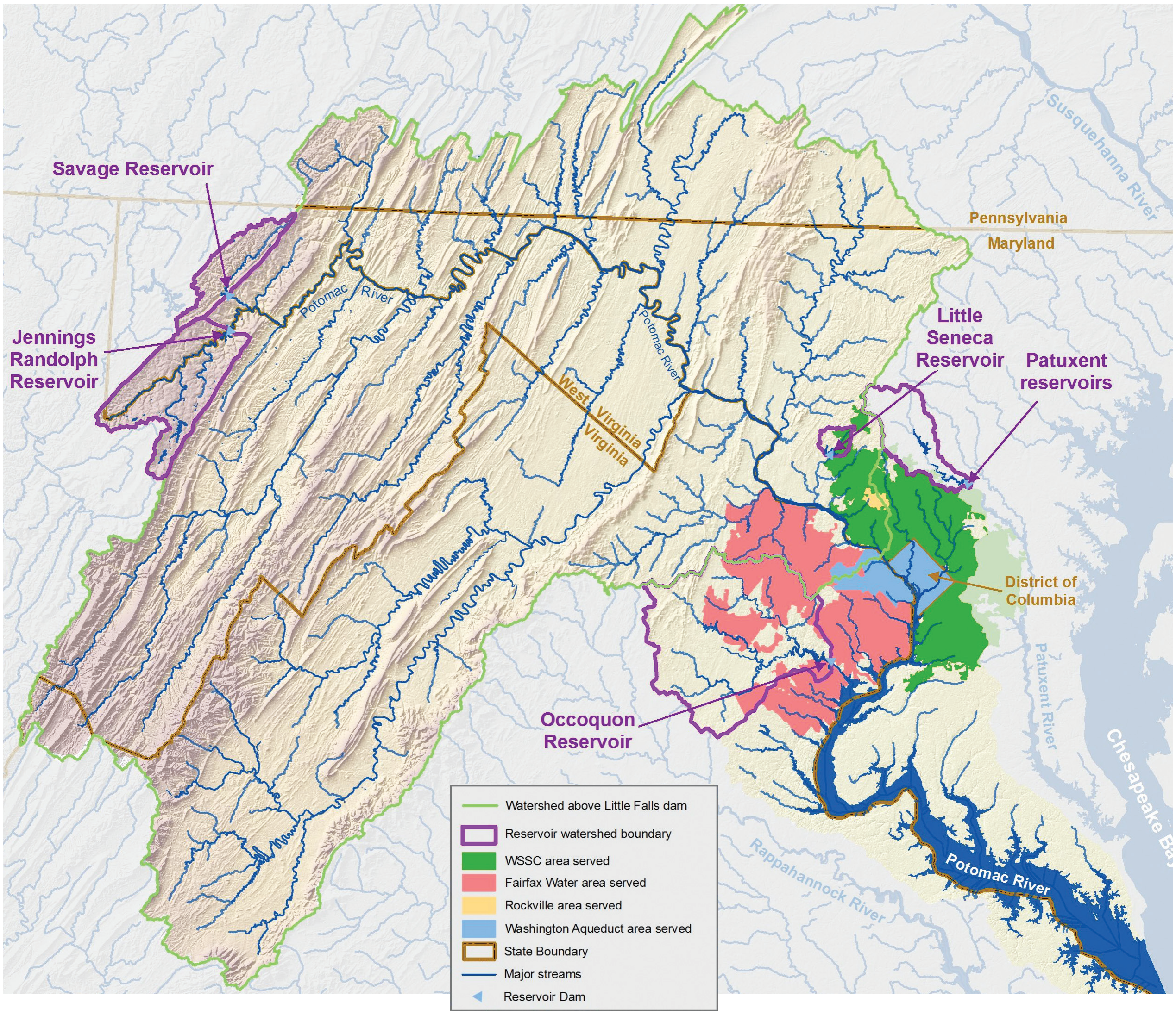


Figure 4.3. *The Potomac River basin includes the Potomac River and its tributaries in four states—Maryland, Pennsylvania, Virginia, and West Virginia—and the District of Columbia.*

Source: Interstate Commission on the Potomac River Basin

and coordination among the regional water utilities to avoid water supply shortages in the WMA during droughts. It coordinates WMA water supply withdrawals from the Potomac River and from off-river reservoirs and recommends releases from upstream reservoirs when forecasted flow in the Potomac River is not sufficient to meet expected WMA demands plus an environmental flow-by recommendation (ICPRB 2012b). Funding for the CO-OP is provided by the WMA's three largest water utilities.

History of Water Supply Planning

Historically, the USACE was the main entity responsible for water supply planning in the basin because it was the only supplier with an intake on the Potomac until the 1980s. Adequate water supply was never an issue until the 1960s, when a combination of decades of steady population growth and several droughts highlighted the potential for a major water crisis in the near term. In 1963 the USACE water use forecasts indicated that, for the first time, demands could exceed flows in the Potomac during dry periods. In 1966 these forecasts were proven accurate as a severe drought for the first time resulted in flows in the Potomac being lower than projected future demand (Hagen et al. 2005).

Despite the dismal forecasts, the number of intakes and the total amount of the withdrawals along the Potomac kept increasing to meet demand. The federal government began to worry about the effects of the additional intakes in combination with droughts on the district's long-term water supply. The district relies on the most downstream intake and, as a result, includes one of the most vulnerable populations in the area during times of drought when flow is low.

To combat anticipated future shortfalls, the USACE proposed a series of structural solutions, including the construction of 16 potential reservoirs. Financial and technical difficulties, combined with strong public opposition to the structural options, left the water utilities and local governments looking for other solutions. Of the 16 projects proposed, only the Jennings Randolph Lake Reservoir was constructed, in 1981. Research at Johns Hopkins University and the ICPRB that began in the late 1970s showed that coordinated use of the stored water in the Potomac basin during droughts produced a greater yield and greatly alleviated the need for additional reservoirs. This research, coupled with increasing political pressure from the federal government, convinced the states and utilities of the need for more cooperative water supply management in the WMA (Hagen et al. 2005).

In 1978 the WMA water utilities and the states of Maryland and Virginia agreed on a formula for allocating the limited water during shortages through the signing of a Low Flow Allocation Agreement (LFAA). Interestingly, the signing of the LFAA was a requirement prior to the WSSC being granted a permit to build a weir at its Potomac intake to ensure supply during extremely low flows. In a memorandum of understanding with the LFAA, signatories agreed to allow the Maryland Department of Natural Resources (MD DNR) to undertake a low-flow study to determine minimum flow rates for protecting the Potomac's natural ecosystem. Despite opposition from the U.S. Fish and Wildlife Service, which advocated for a higher flow, the minimum flow recommended by MD DNR was 100 mgd at the USGS Little Falls gage near Washington, D.C. (Sheer 1983). This 100 mgd flow remains a management goal for the CO-OP.

In 1982 the federal government, the Potomac basin states and District of Columbia, the utilities, and the ICPRB signed eight separate agreements to improve coordinated regional operation of the region's water supplies (Sheer 1983). One of these agreements was the Water Supply Coordination Agreement (WSCA) requiring the major water suppliers to coordinate their operations during droughts in order to minimize the possibility of having to implement the water-use restriction stages of the LFAA. The CO-OP was designated in the WSCA as responsible for coordination of water resources during times of low flow (MWCOG 2013). Storage agreements were also signed, which codified the joint ownership of water storage in upstream reservoirs and the means for operating them for common benefit during droughts (Sheer 1983).

Since its implementation, the cooperative system set out in these agreements has allowed unrestricted demands to be met and has created a framework for identifying and addressing future shortfalls. The WSCA requires a forecast of demands 20 years into the future and, every five years, an assessment of whether or not the current system can meet these projected demands. The utilities have selected the CO-OP to conduct these studies since they began in the early 1990s; it also sets out a payment structure for how future shared water supply resources would be funded (Bencala 2013).

Although efforts taken by the states, utilities, and the ICPRB helped with coordination at these levels, few efforts early on had coordinated the response to drought at the local level. This became obvious in 1999, when the area experienced one of the worst periods of drought on record. In this instance, the state of Maryland implemented water use restrictions, but the District of Columbia had not. This led to a situation where Maryland residents were restricted from outdoor watering and car washing, while D.C. residents who lived on the same street faced no such restrictions. Needless to say, this led to much confusion and frustration in the region. The Metropolitan Washington Council of Governments (MWCOG), the regional planning organization for the Washington, D.C., area's local governments and their governing officials, noticed the variety in the responses to drought at the local level. In response, the MWCOG established a Task Force on Water Supply Issues to review the region's water supply systems, drought emergency plans, and long-term water supply plans and needs.

The task force was also directed to put special emphasis on communication and coordination among local and state governments, water supply utilities, the media, and the general public in the event of another serious drought. One of the central task force recommendations was the need to develop a common set of triggers and actions to be used by local governments and water utilities to ensure a coordinated response to future drought events. At the time of the 1999 drought, each state relied on its own drought plan when determining how to respond to a drought.

The MWCOG acted on this recommendation and in 2000 adopted the Metropolitan Washington Water Supply and Drought Awareness Response Plan: Potomac River System. The document provides a plan of action to be implemented during drought conditions for the purpose of a coordinated regional response. The plan consists of two interrelated components: (1) a year-round plan emphasizing wise water use and conservation; and (2) a water supply and drought awareness and response plan. The year-round wise water use program addresses actions to be taken by the MWA outside of times of drought. The awareness response plan, primarily designed for those customers who use the Potomac River for their drinking water supply, contains four stages and establishes indicators which trigger both voluntary and mandatory restrictions (MWCOG 2001). The actions are directed at customers of the CO-OP system and are tied to water supply system outlooks provided by the CO-OP. In the case of Maryland, this plan overrides the other drought restriction designations the state may implement.

Water Supply Planning Today

Today, the ICPRB serves as a technical resource for WMA's largest water suppliers. Per the WSCA, the CO-OP continues to conduct water demand forecasts every five years. These water demand forecasts estimate the amount of water required to meet customer demand over a 20-year period. The forecasts include a reliability and resource availability analysis that accounts for the water available to meet the forecasted demands and the ability of the system to deliver the water when and where it is needed (ICPRB 2012d). Conducting these forecasts on a five-year interval ensures regular updates and incorporation of recent demographic forecasts, increases the visibility and understanding of the region's water resources, and provides adequate time to conduct research on the physical system and to incorporate modifications based on this research into subsequent studies and planning (Hagen et al. 2005).

The CO-OP also organizes an annual drought preparedness exercise (except when flows are below normal), which is a seven-day simulation of drought conditions to practice coordinated drought operations. The exercise, which includes staff from the CO-OP, the WMA water suppliers, the MWCOG, and the Baltimore District of the USACE, ensures that all stakeholders are properly trained in drought procedures and that drought operations run smoothly. The ICPRB practices communications with providers so they understand the types of requests they might receive. Participants can also provide the CO-OP staff with ideas for future information exchange and collaboration (ICPRB 2012g).

DROUGHT SCENARIOS, SIMULATIONS, AND TOURNAMENTS

Natural hazards such as earthquakes, hurricanes, flooding, wildfires, and drought throughout the world are constant reminders that effective mitigation and response planning is necessary to minimize the negative impacts associated with these events. Exercises or simulations, in addition to planning, have proven to be an effective means to ensure preparedness and test established plans. Such exercises typically involve simulation of the natural hazard, requiring participants to implement and test a plan in actual or compressed time.

Droughts, due to their slow onset and multisector impacts, are challenging to address under the typical emergency exercise framework. Consequently, drought gaming forums or "drought tournaments" have recently been introduced in Canada and Colorado as an alternative means of preparing for drought. There are key differences between a gaming forum and a typical emergency exercise. The gaming forum does not test an existing response plan but instead requires participants to develop new plans in response to a fictitious yet realistic simulation of drought conditions. The participants are judged and scored on the quality of their plans, fostering collaboration through spirited competition.

Jeff Brislawn

The Science and Technology Branch of the Agriculture and Agri-Food Department of Canada developed the drought tournament concept to better prepare the agricultural sector for extreme climate events; it successfully conducted two drought tournaments in 2011 and 2012. The Colorado Water Conservation Board and the National Integrated Drought Information System, in partnership with AMEC Environment and Infrastructure, applied the drought tournament concept as a day-long event in advance of the Colorado Drought Conference in September 2012. The tournament included five teams with a mix of agriculture, municipal water, environmental stewardship, energy, and tourism backgrounds.

Teams were charged with developing drought response plans for each year of a three-year drought applied to a fictitious watershed called "Chance Basin." Teams were scored by referees on how well their response plans reduced vulnerability and potential drought impacts within Chance Basin as well as their approach to long-term drought mitigation. The team with the most comprehensive series of drought response plans won the tournament and was awarded a grand prize. By fostering a competitive yet collaborative environment, teammates from diverse backgrounds were able to work together to determine the most mutually beneficial solutions (Brislawn et al. 2013). In addition to drought mitigation and response, this gaming forum has the potential for use in other planning applications such as long-term water supply and management planning, climate adaptation, and disaster mitigation and recovery.

The Interstate Commission on the Potomac River Basin (ICPRB) has been conducting annual drought exercises for the Washington metropolitan area for more than twenty years. The ICRPB coordinates water supply operations during times of drought for the three major water utilities in Washington, D.C., and the adjacent suburbs of Maryland and Virginia. The drought exercises allow the ICPRB and the utilities to practice communications and to simulate operations of the system as would occur during an actual drought. This is an example of how exercises can build and enhance preparedness for actual drought events.

Additionally, the CO-OP publishes water supply outlooks on a monthly basis between April and October which provide updates on the possibility of water supply releases from the area's reservoirs based on long-term precipitation data, flows, and other information for the Potomac basin (ICPRB 2012c).

The MWCOG, through the Drought Coordination Committee and the Metropolitan Washington Water Supply and Drought Awareness Response Plan, primarily oversees actions at the local government level and communications with residents.

Goals for the Future

According to Karin Bencala, water resources planner at the CO-OP, the commission is constantly working to improve the reliability of its planning model—the Potomac River and Reservoir Simulation Model—and the other tools used during drought operations. It is also regularly undertaking special studies, which recently included evaluating climate change scenarios in its forecasts.

One goal of the ICPRB is to get other entities, those with their own waterworks systems that draw from the Potomac and are not a part of the WSCA, involved in a similar agreement. Although the current approach has alleviated water supply shortages to date, the ICPRB staff knows that a better understanding of what is happening upstream would help it more effectively meet demands and flow-by targets during droughts. Increased coordination is only going to become more important as the population continues to increase both in the district and in upstream areas.

Along these same lines, most of the actions detailed in the Metropolitan Washington Water Supply and Drought Awareness Plan currently only apply to customers of the CO-OP system. The MWCOG would like to expand the audience to capture all water supply system customers in the region.

Finally, the ICPRB's current planning model is proprietary. While model outputs are shared with water utilities, the MWCOG, and other regional stakeholders, they do not have access to the model itself. ICPRB is committed to moving to open-source programs and plans to make the next planning model available to all partners (Schultz 2013).

STATE OF COLORADO

Colorado's location, geography, and complex topography results in drastic climate differences from place to place and from year to year. For example, although the state overall is considered semi-arid with an average annual precipitation of 17 inches, some portions of south central Colorado receive on average only seven inches of precipitation, whereas a few mountain locations receive over 60 inches. The unpredictability in climate brings regular stretches of both extreme wet and dry periods. Colorado's economy relies heavily on tourism and agriculture, two sectors vulnerable to drought. The economic impacts experienced during drought have served as the catalyst for drought and water management policy in the state (Colorado Climate Center 2010).

Drought History

Although Colorado has experienced extended dry periods throughout its history, drought planning in the state did not begin until the state experienced a severe drought in the winter of 1976–77. The drought had severe economic and environmental impacts, leaving ski slopes bare and reservoirs empty (McKee et al. 2000).

Then governor Richard Lamm responded by convening a special council of experts known as the Drought Council to assess the crisis and propose ideas for lessening the economic impacts associated with drought. By 1978, however, heavy snows and spring rains were falling again. With less of a sense of urgency, the proposed actions were tabled. After another round of snow shortages in 1980–81 brought the issues back into the spotlight, Governor Lamm set forth a proposition to develop a state drought plan. The plan would be the first in the state and one of only three adopted drought plans in the country (McKee et al. 2000).

Lamm charged the Office of Emergency Management with development of the plan. The resulting product, the Colorado Drought Response Plan, was approved and implemented in 1981 within a matter of months. Through adoption of this plan, the state identified drought as a major natural hazard in Colorado, established clear mechanisms for monitoring drought conditions and impacts, and communicated water supply and drought information to decision makers.

Other water conservation efforts at the state level complemented the drought plan. In 1991 Colorado passed the Water Conservation Act (HB91-1154), which made it the first western state to enact statewide water conservation legislation. The act required covered entities (retail water providers with annual demands of 2,000 acre-feet or more) to prepare water use efficiency plans for approval by the state. It also created the Office of Water Conservation within the Colorado Water Conservation Board (CWCB) to coordinate the planning for and implementation of those plans.

The state experienced one of its worst droughts on record in 2002. Impacts to municipal water supplies, agriculture, recreation, and streamflows were exceptionally severe. In response, the state increased its water conservation and drought planning efforts. It transferred responsibility for development of the Colorado Drought Response Plan to the CWCB.

In 2004 the state adopted HB 04-1365, which expanded the mission and duties of the Office of Water Conservation from promoting water efficiency to promoting water conservation and drought mitigation planning. The office was aptly renamed the Office of Water Conservation and Drought Planning. At this time, the CWCB conducted a Drought and Water Supply Assessment to improve the state's understanding of drought and drought impacts, and the project engaged Colorado water users in better preparing for future droughts (CWCB 2004).

Through legislative action in 2007, the state funded a dedicated staff person to focus on drought response. Revising the state drought plan quickly became the top priority. The CWCB conducted an update of the Drought and Water Supply Assessment to obtain new information on the current status of drought planning and preparedness, water conservation planning and programs, and water supply (CWCB 2007).

In 2010 the state undertook its first comprehensive overhaul and update of the Drought Response Plan. The plan evolved from a 20-page response-focused plan to a proactive mitigation plan of more than 400 pages, which includes a response component, and it is currently used today.

State Drought Mitigation and Response Plan

The State of Colorado adopted its first drought plan in 1981. Since its original adoption, the plan has been revised five times. The plan received only minor updates the first four times; in 2010, it was completely overhauled. Revisions included incorporating mitigation into the plan and aligning the plan's mitigation element with the standard state mitigation planning requirements of the Disaster Mitigation Act of 2000 to ensure consistency with the Natural Hazards Mitigation Plan (NHMP). These requirements include a vulnerability assessment, improved monitoring, and compliance with the Emergency Management Accreditation Program (EMAP) standard.

Prior to beginning work on the Drought Mitigation and Response Plan (DMRP), the state formed a Drought Mitigation and Response Planning Committee (DMRPC) to oversee plan development. The DMRPC comprised members of established plan task forces, including representatives from federal and state organizations. The DMRPC sought input and technical expertise from a variety of stakeholders: agricultural and conservation organizations, wildfire and forest representatives, utility providers, and representatives from the recreation and tourism industry. It also prepared a Stakeholder and Public Participation Plan to ensure meaningful public input. The committee received and incorporated substantial public input into the final plan.

The DMRP includes three major sections: mitigation and monitoring, vulnerability, and response.

Mitigation and Monitoring. The plan's mitigation strategy follows the four-step mitigation planning process of the Federal Emergency Management Agency (FEMA) shown in Figure 4.4. The strategy outlines the goals of the plan and specific prioritized action items intended to meet those goals. In order to maximize available resources, the strategy identifies a lead agency

Figure 4.4. *The four-step mitigation plan process of the Federal Emergency Management Agency (FEMA).*

FEMA

or entity and funding sources for each action item at all levels of government and for nongovernmental organization stakeholders. Finally, the strategy includes information on the status of each action item. This allows the state to measure its progress on the implementation of drought mitigation efforts. Many of the mitigation actions are ongoing and can occur during drought and non-drought times.

Monitoring of the state's water availability is an ongoing effort and is accomplished through monthly meetings of a Water Availability Task Force (WATF). Members of the WATF include water supply specialists from local, state, and federal governments, experts in climatology and weather forecasting, and vested stakeholders, mostly water providers. This task force monitors snowpack, precipitation, reservoir storage, and streamflow using a variety of indices, including the Surface Water Supply Index, the Palmer Drought Severity Index, and the Standardized Precipitation Index. All the indices were evaluated and modernized in an effort that ran parallel to the plan revision; they are described in detail in Annex D of the plan. These regular meetings are a forum for synthesizing and interpreting water availability information, helping with early warning, and positioning the WATF to recommend activation of the DMRP by the governor when conditions are warranted.

Vulnerability. The plan includes a detailed vulnerability assessment that discusses the past and potential impacts of drought on state assets (state-owned or state-operated buildings, critical infrastructure, state lands, instream flows, and fish hatcheries) as well as six private and economic sectors: agriculture, energy, environment, municipal and industrial, recreation, and socioeconomic.

The vulnerability assessment is both quantitative and qualitative and includes a review of state and local hazard mitigation plans, an extensive literature review, and interviews with individuals knowledgeable about particular sectors or assets. It identifies risks and impacts as well as adaptive capacities to improve the management of future incidents. The assessment also includes an economic valuation of the impacts, estimating potential losses to each state asset and sector. This information can be used to compile an ongoing record of drought impacts in order to better define future drought vulnerability.

Response. The Colorado Drought Response Plan, a separate annex in the DMRP, details response actions during times of drought. The plan outlines a three-phase drought plan cycle from monitoring to full plan implementation. Also detailed are indicators, impacts, and actions to be considered at each phase, from normal conditions through moderate and severe drought.

It also includes a framework for response which streamlines communication from the ground up to the governor's office. Under this framework, a network of task forces identifies needs and guides response resources to the state and affected local jurisdictions to reduce impacts.

The Plan's Improvements and Successes

The DMRP improves how the state monitors, mitigates, and responds to drought. The plan meets the highest level of established standards and is consistent with relevant federal, state, and local plans, processes, and requirements. It meets FEMA and EMAP standards and requirements, meaning that the plan meets agreed-upon national standards for emergency management. The mitigation component of the plan conforms to the Standard State Hazard Mitigation planning requirements of the Disaster Mitigation Act of 2000, making the state eligible for financial and technical assistance following presidential disaster and emergency declarations. The plan is also an annex

UPPER COLORADO RIVER REGIONAL DROUGHT EARLY-WARNING SYSTEM

The National Integrated Drought Information System (NIDIS) selected the Upper Colorado River basin to pilot the first drought early-warning and information system in the United States. NIDIS worked with the Colorado Climate Center (CCC) on monitoring efforts as well as the development of the early-warning system. The system enhances local, state, and regional capabilities; builds better partnerships; and provides local expertise to the U.S. Drought Monitor.

NIDIS and the CCC conducted a series of interviews with a variety of stakeholders, including water users and providers, resource managers, and watershed protectors in the basin. They identified drought triggers and indices, monitoring gaps, widely used data and products, and the data and information needs of users.

Presently, they use the information they obtain to produce weekly drought and water assessments. These assessments put current hydrologic information into historical perspective and provide current updates on local conditions and, less frequently, on regional conditions. The assessments cover precipitation, streamflows, reservoir levels, snowpack conditions, water demand, National Weather Service forecasts, and any changes to the U.S. Drought Monitor.

This early-warning system provides timely and effective information that allows individuals and communities to prepare for drought, reduce vulnerability to drought conditions, and plan effective responses. NIDIS and the CCC continue to talk with stakeholders and evaluate the system to provide an accessible, "one-stop-shop" data resource.

Regional drought early-warning systems for the Upper Colorado River basin and other locations across the U.S. are located at **www.drought.gov/drought/content/regional-programs/regional-drought-early-warning-system.**

to the NHMP, which ensures consistency between the plans and makes the state eligible for nonemergency Stafford Act assistance and FEMA mitigation grants. Additionally, the Drought Response Plan Annex has been designed to comply with the National Response Framework (NRF) and National Incident Management System protocols, improving consistency and coordination between the state and national government response strategies. Finally, the plan is consistent with local hazard mitigation plans; this is crucial to building a more effective mitigation program over time (CWCB 2010a).

Continued monitoring and evaluation of monitoring indices have also enabled the state to improve its drought-monitoring capabilities and modernize its drought-monitoring indices. This ensures that the state has the information necessary to determine the early onset of drought and activate the assessment, response, and mitigation portions of the DMRP at the appropriate times.

The development of a comprehensive drought hazard vulnerability assessment allows the state to assess the threat of potential drought hazards for various state assets and sectors. Additionally, the state is better able to target its limited mitigation resources by understanding the threats and ways to reduce them, identifying the most vulnerable assets and sectors and their locations, and considering adaptations to improve the capacity to manage future incidents.

The state has also increased the accessibility of the response elements of the plan by placing them in a separate annex, and has revised and modernized the response framework. The framework can be partially or fully implemented and provides a system for responding to drought that ranges from the early onset to sustained periods of drought conditions. The framework also identifies all of the agencies involved in response and assigns them specific roles and responsibilities. It is designed to comply with the NRF to provide a seamless link between local-state, state-state, and state-federal operations.

The continued assessment of the number, constituency, and makeup of the WATF ensures that the right representatives are at the table and increases coordination within and among state and federal agencies. The coordination and sharing of information between local governments and water suppliers are largely voluntary in Colorado; therefore, this forum for information exchange is critical.

The state has been making active progress in the implementation of the drought mitigation efforts set forth in the mitigation strategy of the plan. Of the 35 actions identified prior to 2010, 34 have been completed or are considered ongoing. The plan also includes a detailed maintenance process for monitoring, evaluating, and updating the plan. The DMRPC meets yearly in conjunction with regular meetings of the WATF to discuss the progress made on mitigation actions, lessons learned from response to drought conditions, the drought outlook and any preparation needs, and the response procedures in the plan (CWCB 2010a).

Supporting Local Drought-Planning Efforts

One of the most important revisions in the 2010 DMRP is an expressed commitment to support local drought-planning efforts and the development of additional tools and resources. In Colorado, municipal providers and local governments are not required to adopt state-approved drought mitigation plans. Despite the growing uncertainty about future water supplies and the increasing importance of local drought planning, few communities have expressed a desire to conduct drought planning. The Town of Firestone adopted a Drought Management Plan in 2012, and three additional plans are currently under development (Finnessey 2013). The CWCB has made a significant push to get more communities thinking about local drought planning. State staff meets regularly with local utilities and water suppliers to provide drought management information, technical assistance, and information on available financial assistance. The CWCB has developed a number of tools to encourage drought planning at the local level.

Drought Planning Toolbox. The Drought Planning Toolbox is a web-based tool that provides up-to-date information for drought management. Developed in 2010, the toolbox contains information about funding sources, technical resources, regional and field contacts for drought-related information, and internet resources. It also provides current drought status details and information designed to educate the public and raise community awareness about drought (CWCB 2010b).

Guidance Document and Sample Drought Plan. In 2010 the CWCB developed a Municipal Drought Management Plan Guidance Document to assist municipal providers and local governments with their drought-planning efforts. This guidance document serves as a reference tool that municipalities throughout the state can use in developing local drought management plans. It provides a comprehensive background on municipal drought management planning and recommends drought mitigation and response planning steps and components useful for developing local plans (CWCB 2010c).

In 2011 the CWCB released a municipal drought management sample plan to show how the guidance document can be used to develop a municipal drought management plan (CWCB 2011).

Grants. The CWCB oversees the Water Efficiency Grant Program, which provides financial assistance to communities, water providers, and eligible agencies for water conservation–related activities and projects. Eligible organizations, as well as state and local governments and agencies, can receive funding to develop water conservation and drought plans, implement goals outlined in these plans, and educate the public about water conservation (CWCB n.d.b). The state offers four types of grants: Water Conservation Planning Grants, Water Conservation Implementation Grants, Drought Mitigation Planning Grants, and Water Resource Conservation Public Education and Outreach Grants. The Drought Mitigation Planning Grants are available specifically to help water providers or state and local governmental entities develop drought mitigation and response plans. The Town of Firestone took advantage of this grant when developing its Drought Management Plan (CWCB n.d.a., Finnessey 2013).

Drought Tournament. In September 2012 the CWCB and NIDIS, together with AMEC Environment and Infrastructure, held the state's first day-long "drought tournament." An alternative means of engaging stakeholders in the preparedness process, the tournament differed from a typical emergency exercise because participants developed a response plan "on the fly" rather than testing an existing response plan. (See "Drought Scenarios, Simulations, and Tournaments," p. 64 for more details about the Colorado drought tournament.)

Conclusion

Colorado was a leader in drought planning in the 1980s and early 1990s, adopting one of the first drought plans in the nation and enacting the first statewide water conservation legislation. Planning efforts tapered off after these initial successes, and the state began to lag behind. After the devastating effects of the 2002 drought, the state again emerged as a leader in drought planning. It undertook a complete overhaul of its drought plan and shifted the focus from reacting to drought to proactively mitigating drought impacts. It also developed a number of tools and resources to support drought planning efforts at the local level.

Over the past decade drought planning has been elevated to a new level in Colorado, and the state continues to build on this momentum. The CWCB is currently in the process of updating the 2010 Drought Mitigation and Response Plan to include more climate change considerations and to track the progress of plan implementation. Additionally, in May 2013, the governor directed the CWCB to begin work on a state water plan with drought being a major focus (Colorado 2013). Together the DMRP and the state water plan will help ensure Colorado's water resources are sufficient for generations to come.

MURRAY-DARLING BASIN, AUSTRALIA

Drought has always been and continues to be a feature of the Australian landscape and way of life (Kendall 2010). Australia has the lowest rainfall and one of the most variable rainfall patterns of all inhabited continents (ABARES 2012). The unreliability of the climate has resulted in a history of widespread drought. Some of the most severe droughts include the periods of 1895–1902 (known as the Federation Drought), 1913–1915 (known as the First World War Drought), 1937–1945 (known as the Second World War Drought), 1958–1968, 1982–1983, 1991–1995, and 2002–2009 (known as the Millennium Drought).

The Murray-Darling basin is Australia's largest river system and one of the biggest systems in the world. It covers 1,061,469 square kilometers, approximately one-seventh (14 percent) of the total area of Australia, and passes through five states and territories: South Wales, Victoria, Australian Capital Territory, Queensland, and South Australia. The basin is home to more than two million people (including about 30 Aboriginal nations), with another 1.3 million people outside of the basin dependent on its water resources. It is also Australia's most important agricultural region, containing over 40 percent of all Australian farms, producing one-third of Australia's food supply, and supporting over a third of Australia's total gross value of agricultural production (MDBA 2008a).

Water availability in the Murray-Darling basin is subject to large variations throughout the year, between years, and over longer periods. The volume of water in the basin is lower and more variable than most river systems around the world (MDBA 2008a).

History of Water Planning

Australia has a long history of water planning. The severity and frequency of droughts have been influential in shaping water policy. In response to the impacts of the Federation Drought, the commonwealth and states began drought protection negotiations in the basin. Thirteen years later, in 1915, the River Murray Waters Agreement was signed. It established the River Murray Commission in 1917 to manage the efficient sharing of the Murray's waters between the states (Sennett et al. 2012).

The agreement was amended several times over the next few decades as community values shifted and economic conditions changed. Water quality became a big concern as the basin experienced elevated salinity levels during the drought in the late 1960s. The commonwealth and states began meeting to discuss how to tackle resource and environmental degradation problems in the Murray-Darling basin in the early to mid-1980s. They concluded that a highly varied water management scheme between states had not proven effective in addressing the water quality and environmental degradation problems facing the basin. In response, in 1992, they negotiated the final version of the Murray-Darling Basin Agreement (MDBA), which replaced the 1915 River Murray Waters Agreement (Sennett et al. 2012). Three new institutions were established as a part of the agreement: the Murray-Darling

Basin Ministerial Council (MDBMC), the Murray-Darling Basin Commission (MDBC), and the Community Advisory Committee (Sennett et al. 2012).

Despite the new agreement, conditions in the basin continued to deteriorate. The focus of water policy shifted to market-based competitive reforms. In 1994 the Council of Australian Governments (COAG), an intergovernmental forum dedicated to promoting policy reforms of national significance, developed the Water Reform Framework. The framework was designed to create more efficient water markets and included the creation of tradable water licenses and trading in water allocations or entitlements. In 1995 the MDBMC capped surface water diversions. The cap set a total volume of water that could be extracted each year for consumptive purposes and ended the issuance of new water rights in the basin. These market-based reforms proved to be very effective in limiting the economic impacts of the Millennium Drought; however, they did not necessarily provide a sustainable level of diversions (Sennett et al. 2012).

In 2002, given this assessment, the MDBMC established an intergovernmental agreement to provide $500 million over five years to address overallocation in the basin by recovering water for the environment. The program, known as The Living Murray (TLM) program, was a partnership between the commonwealth and states designed to recover 500 GL (gigaliters) of water to be used to improve the health of six iconic sites in the basin.

Increasing frustration with the slowness in implementing the 1994 reforms, however, led to the approval of a more detailed package of reforms under a new COAG intergovernmental agreement—the 2004 National Water Initiative (NWI). Under the NWI, all jurisdictions agreed to a set of key elements to include within their water planning frameworks and the closely linked water access entitlement frameworks (Bark 2013). That same year, the commonwealth established the National Water Commission (NWC) to advise it on national water issues and to monitor the implementation of the NWI. The NWC assessed the progress of water reform in the basin in 2005, found it to be insufficient, and withheld incentive payments to the states (Sennett et al. 2012).

The Millennium Drought exacerbated the concern that the consensus-based approach had failed to protect the basin's environmental assets. In January 2007, Prime Minister John Howard announced the National Plan for Water Security. The plan included reconstituting the MDBC as a commonwealth government agency reporting to a single commonwealth minister and charged it with developing a new basin plan that would impose a revised cap on diversions. When the commonwealth asked the states for a referral of power to "enable it to manage the Basin in the national interest," four of the five states agreed. When further discussions failed to reach an agreement, the commonwealth introduced legislation based on its existing legislative powers.

The Water Act of 2007 established an independent MDBA with the functions and powers, including enforcement powers, to oversee water planning for the basin as a whole for the first time (Sennett et al. 2012). The MDBA was charged with preparing a basin plan for adoption by the minister that included setting sustainable limits on water that could be taken from surface and groundwater systems across the basin. It was also directed to advise the minister on the accreditation of new state water resource plans to ensure consistency with the basin plan (ADSEWPC 2012c).

Basin Plan 2012

The MDBA prepared a plan for the Murray-Darling basin as it was charged to do under the Water Act of 2007. Efforts began with the release of the Guide to the Proposed Murray-Darling Basin Plan in October 2010. A draft plan was released in November 2011, and a revised plan was submitted for review and comment in May 2012. The final plan, Basin Plan 2012, was signed into law in November 2012. The authority used a collaborative planning process that involved a variety of stakeholders, including people living in the basin, industry, environmental and indigenous groups, scientists, and basin officials and ministers (MDBA 2008c).

The adoption of Basin Plan 2012 marks a new era of water management in the basin. It is the first plan adopted at the national level, ending the fragmented management of the basin and permitting one authority to manage the system at an integrated, basin-wide level. The plan establishes a sustainable diversion limit (SDL) that ensures a better balance between water available for human use and water allocated for environmental purposes. Historically, an environmental allocation did not exist, which meant that protecting or restoring the environmental assets of the basin came last after water was allocated for all other purposes such as human consumption and irrigation. Basin Plan 2012 requires the return of an average of 2,750 GL of water to the environment annually by 2019, and allows an additional 450 GL of environmental water to be recovered annually by 2024 if this can be done without worsening economic conditions.

Although the SDL is concrete, the plan offers flexibility in how goals are achieved. Governments can propose projects that deliver equivalent environmental outcomes with less water as long as other outcomes are not sacrificed in the process (ADSEWPC 2012a). Additionally, states must have their water resource plans accredited by the minister to ensure consistency with Basin Plan 2012. The plan is the first proactive approach taken to planning for drought at this level. It minimizes the risks associated with future drought events by bolstering the resilience of the national environmental systems of the basin.

Achieving Basin Plan 2012 Benchmarks

Achieving the SDL established in Basin Plan 2012 will be challenging. It will require efforts from all levels: commonwealth, state, and local. Since the plan was recently adopted, measuring implementation successes at this stage would be premature. The commonwealth, the entity spearheading the basin management reform, has made several strides toward achieving the goals set forth in Basin Plan 2012. At the state and local level, however, jurisdictions are still largely working to determine how they can achieve the established goals. Most concerning is the issue of how these strategies will be funded.

Through a 10-year initiative known as the Water for the Future Initiative, the commonwealth has committed $12 billion to support efforts to increase the amount of water available for environmental purposes (Water Recovery Team 2012). It is acquiring environmental water through direct buybacks of water entitlements from irrigators and through savings from infrastructure upgrades. This primarily occurs through two programs: Restoring the Balance in the Murray-Darling Basin and the Sustainable Rural Water Use and Infrastructure Program (SRWUIP). The commonwealth has committed $3.1 billion to the Restoring the Balance in the Murray-Darling Basin program to purchase water entitlements from willing sellers. Since the plan was adopted in late 2012, it has purchased over 1,200 GL of water entitlements from sellers, mostly irrigators and farmers, to restore the environment (ADSEWPC 2012b). It has also committed $5.8 billion to increase water use efficiency in rural Australia through the SRWUIP. The program invests in key rural water projects that will support sustainable irrigation and conserve water by upgrading outdated and leaky irrigation systems (ADSEWPC 2012b).

The commonwealth has undertaken several other efforts to increase environmental water. It dedicated $1.77 billion to the implementation of measures to allow the 450 GL in additional water to be recovered without socioeconomic detriment. Measures include an associated constraints management strategy—largely engineering solutions—to fix, remove, and alter some of the constraints in the system by removing chokes, elevating bridges, and increasing the size of outlets on dams (MDBA 2008b). Additionally, it developed a National Urban Water Desalination Plan that supports infrastructure projects and research in desalination, water recycling, and stormwater harvesting and reuse. Each project listed in the plan is accompanied by funds for implementation (ADSEWPC 2013). The commonwealth also oversees a Water Efficiency Opportunities Program to support and encourage water efficiency in commercial and industrial sectors (ADSEWPC 2011b). It has committed $200 million to the Strengthening Basin Communities program, which provides grants for local governments in the basin to assist in communitywide planning efforts and provides competitive grants to support projects that reduce demand on potable water supplies (ADWEWPC 2011a). In addition, the commonwealth has committed $1.5 billion to the Water Smart Australia program aimed at accelerating the development and uptake of smart technologies and practices in water use across Australia (ADSEWPC 2012b).

The commonwealth is required to hold and manage the water it acquires in accordance with the environmental water plan included in Basin Plan 2012. The use of commonwealth environmental water is supported by a network of environmental water partners throughout the basin, including environmental water advisory groups, catchment management authorities, scientific organizations, river operators, and state governments. Together, they decide when to use the water and where it is best used. They also help deliver the water and monitor outcomes. As of March 31, 2013, 2,267 GL of the commonwealth environmental water had been delivered to rivers, wetlands, and floodplains of the basin.

Although the commonwealth is spearheading basin reform and has made significant advances in increasing environmental water, states will also play a large role because rights to use and control water in Australia are vested in the state. Each state has multiple catchments and each catchment has its own SDL that the state is responsible for meeting.

States manage their water, determining how to meet SDLs and allocate entitlements, through their water resource plans and associated resource operations plans. The water resource plans state how much water is available and set the principles for sharing the water amongst competing interests. The resource operations plans detail implementation, including the rules for trading of water allocations, the operation of water supply schemes, and the sharing of water resources at any point in time (ADSEWPC and Chinese MWR 2006). Allocating water for the environment and getting their plans accredited by the minister are additional requirements states will now have to meet in their water resource plans.

States are currently updating these plans, but none have been completed or submitted for accreditation to date. These plans will largely determine how the states will meet their established basin goals.

Comparison to the U.S.

Like Australia, the United States faces a multitude of water challenges, including growing populations, rising economic and energy demands, and environmental problems. And like Australia, these issues have been exacerbated by climate change and its affects, which include prolonged drought and extreme flooding. In both the U.S. and Australia, the frequency and severity of droughts are expected to rise.

These persistent and emerging water challenges caused Australia to reassess its approach to water management. Its innovative new water strategy signals a growing commitment to more comprehensive, integrated water management shaped by a variety of political, economic, environmental, and social factors. Key features of the new strategy include federalizing water data collection (creating a new federal repository of water monitoring and measurement information), requiring greater regulatory reporting, creating a market for water trading, allowing for the purchase of water entitlements from willing sellers to restore aquatic ecosystems, increasing on-farm efficiencies and stakeholder participation, decentralizing water decision making, clarifying institutional roles and responsibilities through formal legislation and changes in water rights, and moving to full-cost recovery for water infrastructure and services. The strategy serves as a strong example of how to successfully manage multiple competing interests while managing water supply (Christian-Smith et al. 2011).

A key takeaway from this case study is how long it takes to develop a comprehensive water management strategy—even if all parties involved are dedicated to the effort. In Australia, the commonwealth had to develop federal legislation, gain state support, and raise billions of dollars to buy entitlements and invest in infrastructure. The Water Act passed in 2007, and the commonwealth and states are still determining in 2013 how to implement the policies set forth in Basin Plan 2012. Although some places in the U.S. have made strides toward more comprehensive, integrated water management, there is room for improvement. Traditionally, few soft-path solutions have been introduced, human systems and ecological systems have been managed separately or not at all, and economic tools are ineffective or absent, with few consistent water-pricing approaches and little effort to permit markets (Christian-Smith et al. 2011). This is especially true at the national level, where more than 30 federal agencies, boards, and commissions have water-related programs and responsibilities, but few of these agencies' central missions are related to water and there is little coordination between the agencies (Christian-Smith et al. 2011).

By integrating some of the key features of the water reform effort in Australia, at any level, the U.S. will be better positioned to meet the growing water challenges facing the nation.

CHAPTER 5

Framework for Drought: Conclusions

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Chapter 1 makes clear that drought, especially prolonged drought, brings with it numerous impacts that can be detrimental to the communities experiencing it. Documenting those impacts establishes a set of expectations against a baseline of normal conditions, so that a community can prepare for future droughts. But effective mitigation of drought involves more than simply knowing what to expect. It involves the use of planning to determine precisely what the community is in a position to do to reduce those impacts prior to and during drought. The goal is to make a community better able to handle the stresses caused by drought or, put another way, to make the community more drought-resilient through planning.

This resilience can take a number of forms; ideally, it should encompass as many of them as possible. It should envision improvements in community conditions prior to and during drought with regard to environmental protection, water quality, mental and physical health of residents, protection of structures and infrastructure, economic resilience, and precautions against potential secondary hazards such as wildfires. In other words, planning for drought is better if it is more comprehensive in scope. Best practices should tie in well with other measures for addressing drought.

Nonetheless, there are clear-cut starting points for even the most comprehensive approach. Drought is essentially about a shortage of water compared to normal expectations of precipitation. Best practices must deal with the fundamental issue of how the community now uses its water, which uses are most vital during a period of prolonged drought, which uses can most easily and acceptably be reduced or even prohibited, and how the best adjustments can be achieved with the fewest negative impacts on the overall welfare of the community. Some of these assessments will inevitably also raise questions about how equitably and efficiently the community uses water even under normal conditions. Long-term, perennial reductions in water use that leave a community more efficient may also make it more resilient and adaptable in the face of crisis.

For a comparison, think about the overall position of the U.S. with regard to energy efficiency. As U.S. per-capita energy consumption begins to reflect the use of more energy-efficient vehicles and appliances, as well as increased conservation awareness, the nation's reliance upon—and vulnerability to—disruptions of energy supplies decreases, making it more energy-resilient. A similar public ethic with regard to water consumption may in time make us more resilient in the face of drought. Chapter 1 notes that, to some extent, this has already happened. The introduction of more water-efficient fixtures and appliances has had a leveling impact on our water use in spite of a growing population. Our communities can still make much more progress.

In order for an enhanced public water ethic to take hold, we need to better understand how individual communities and regions use water in order to identify and target strategic opportunities for improvement. As the contrast between New York and California highlighted in Chapter 1 demonstrates, there are wide variations in the nature of water use across the U.S. In the cited example, New York primarily uses water to generate power, while California uses it to irrigate crops. Those two situations yield very different strategies for mitigating drought.

Most of that pattern of use is related to how we price water, which entails a close look at the many hidden or explicit incentives built into a community's system of pricing. Are water prices sending the desired message? Are they skewed for political reasons that may no longer be appropriate or relevant to current problems? Do they reflect understandings of water supply and demand that have become outmoded in the face of new realities? All of these questions should at least be on the table for public visioning and goal-setting exercises related to drought, in order to highlight opportunities for increased community drought resilience. A community cannot easily confront an economic anachronism or distortion that its planners and resource managers have not adequately explained. When the reality of effective drought mitigation requires some upward adjustment of water prices, it may be difficult or nearly impossible to win substantial public support without a widespread understanding of the objectives behind such a change and how they would be implemented. Often there are legal and institutional barriers that must be surmounted. There is no shortcut or effective substitute for good public engagement on an issue like drought. There is more than mere bravado in the old slogan, "Whiskey is for drinking, water is for fighting." Water fights, however, can also be the upshot of poor public education on the underlying issues. Public ignorance of water issues must become a relic of the past. Bad decisions lead to intolerable consequences.

This report has outlined a number of best practices in its case studies and its discussion of the resources and tools available to community planners for addressing drought. Between growing populations in most areas of the U.S. and the accumulating impacts of climate change everywhere, some of which include an increased propensity for drought, the communities most likely to thrive in the face of adversity will be those that embrace an alternative future for which they have adequately prepared. They will do this by maximizing their use of drought-related resources and tools—such as the Drought Risk Atlas—to better understand local drought occurrence, lessons from other communities, the emerging science, and advanced planning techniques to improve their competitive positions. This is already becoming the case with other types of hazard mitigation. Communities like Roseville, California, have learned to use their comprehensive approach to climate change and hazard mitigation to market themselves as safe places to invest (Schwab 2010). These communities have often spent years cultivating a political culture of preparedness for hazards, but the rewards of having invested energy and thought in this manner are significant.

A community with a secure water supply protected from overuse in a drought crisis and that treats drought as a serious hazard can place itself in a similar position. In short, communities that research best practices in drought mitigation and adapt those practices to their own needs and circumstances are in the best positions to protect and secure their own futures.

COMMUNITY AND REGIONAL BENEFITS OF DROUGHT MITIGATION

What specific benefits can a community derive from drought mitigation practices? Chapter 4, which offers a series of case studies, identifies a series of best practices connected with the communities studied.

Here is a review of how those communities benefited from those identified best practices.

Establishing a Diverse Committee or Task Force

The Hualapai gained a sense of transparency and broad buy-in as a result of a highly inclusive planning committee that reached both community members and leaders. In a time of heightened public skepticism of the political process, this type of victory is critical, and its value is not limited to tribal governments. Much larger entities, like Athens-Clarke County, have used deliberate outreach to the universe of stakeholders to encourage widespread attention to the issue and to develop public awareness. The key point is that it is often the uninvited and ignored segments of the community, both powerful and marginal, that are most likely to provide the tripping point for the failure of what might otherwise have been an effective program for drought mitigation.

Bottom line: Diverse committees and task forces can help communities find a much easier path to implementation. These strategies lay the proper groundwork for public acceptance of both the problem and the need for an effective plan of action.

Community Education

Albuquerque illustrates a case where much of the action to reduce long-term water demand depended on the awareness of private property owners, who can translate good ideas into personal best practices, such as choosing more drought-resistant landscaping for their particular plots of land. Development and widespread distribution of guides on critical water-conservation topics educates but also empowers individual property owners and honors their own good sense and property rights. Clearly, Albuquerque has also used regulations to achieve its goals; however, public awareness and support can greatly increase compliance.

Bottom line: Effective public education gives residents the power to move their community toward water conservation goals that help mitigate drought. It can make clear when and why the community has entered into a state of emergency that justifies further restrictions, but it will also make it easier to keep the community on a long-term trajectory toward sustainability in water use.

Regulations for Water Conservation

What works well on a small scale can often be scaled up. The regulations for the Civano development in Tucson may have come about in response to a particular visionary proposal for a sustainable community. It is also clearly easier to establish a major impact on a new development than to retrofit an existing community. But the question planners and their communities tend to ask most often is whether other communities have tried a particular regulatory approach before, and if so, what results they have achieved. It is a sensible question, one that assures a proper degree of caution in moving forward, but taken too seriously, it can also be limiting.

By most standards, the Civano approach was bold. It allowed the city of Tucson to gain valuable experience with such a regulatory approach, and being at the front of the learning curve has its advantages. Tucson was able to take advantage of the opportunity to learn on a modest scale with one development, but communities can also translate that experience into broader, bolder initiatives that address all development within the community.

Beyond regulations for new development that target water conservation on a more general basis, it is also important that communities develop special regulations held in abeyance for use in special circumstances—that is, during a prolonged drought—and establish clear and identifiable triggers for activating those regulations, with an eye to more drastic water conservation under emergency circumstances. But note that, as with energy conservation measures, it makes more sense to have raised the bar (or lowered consumption levels) earlier, in order to make the drastic measures less drastic than they might otherwise have to be.

Bottom line: Communities adopting water conservation regulations gain both valuable experience in better managing water consumption and measurable gains toward sustainability goals.

Incentives for Water Conservation

An earlier PAS Report, *Planning for a New Energy and Climate Future* (Shuford, Rynne, and Mueller 2010), cites an experiment in Santa Fe, New Mexico, to provide incentives for retrofitting existing housing with new toilet features as a means of reducing water demand in the face of a growing population and new development. As part of the program to offset new demand, developers are required to retrofit old houses with more water-efficient new toilet plumbing before they can draw permits for new construction. This is certainly a worthy answer to questions about what communities can do about existing developments that are not subject to newer building codes (with the exception of a change or expansion of existing uses). It also underscores the essential difference in method between regulations and incentives. Regulations work very well (if properly enforced) in regulating the conditions affecting new construction. Incentives work better in inducing existing property owners and residents to comply with the overall goals of a water conservation program, where new code requirements could not typically be applied. Because most communities embody some combination of the new and the old, combining incentives with regulations produces a more comprehensive strategy.

Again, as with regulations, incentives already in place under normal conditions to induce changes in behavior, such as more water-conserving landscaping practices, can be ramped up under drought conditions to achieve more drastic cutbacks. They are more effective, however, when starting from a sound base of water conservation than when truly drastic measures must ameliorate the results of only moderate conservation achievements prior to the drought.

Bottom line: Incentives for conservation in existing development provide an effective complement to regulations controlling the nature of new development, such as zoning, subdivision controls, and building codes.

Developing a Plan

It is tempting, when the bar is still generally set too low, to say, "Develop a plan, any kind of plan." But just getting busy with planning is not really an adequate answer to drought. Although Chapter 3 outlined the use of several major types of plans for addressing drought, the answer as to what is most effective will vary from one community to another. The choice depends on the specific needs and political realities of the situation, and while some plan is generally better than no plan, the appropriate vehicle for planning for drought mitigation and preparedness is primarily a matter of what works and what is most likely to be implemented successfully.

It also matters who is taking the lead in developing the plan. Thus, for Tampa Bay Water, it made the most sense in the midst of crisis to develop a stand-alone plan for water-shortage mitigation. For communities not facing an immediate crisis but anxious to plan for the eventuality, it makes perfect sense to include provisions addressing drought somewhere in the comprehensive plan, in whatever element seems best. Options include green infrastructure, natural resources, land use, water management, and environment, among other possibilities, depending on the structure and organization of the comprehensive plan. Equally important, there are very few communities, if any, that can justify not at least mentioning drought as a potential hazard in completing a local hazard mitigation plan to meet the Federal Emergency Management Agency requirements for hazard mitigation grant eligibility under the Disaster Mitigation Act of 2000.

Bottom line: It is important for every community to address drought in one or more types of plans used within the community, but it is just as important to make good judgments about which types of plans are most appropriate and to explain those decisions clearly.

Drought Exercises and Training

The best plans can be undermined if there is a lack of experience in implementing them. One way to gain experience prior without directly suffering through a drought is to use simulation exercises, but the value of such exercises may well stem from experience in dealing with drought. Thus, it is not surprising that the Section for Cooperative Water Supply Operations on the Potomac River (CO-OP) of the Interstate Commission on the Potomac River Basin (ICPRB) now conducts an annual drought-preparedness exercise involving staff from multiple agencies throughout the region. Such simulations can help ensure smoother implementation of drought measures when the time comes.

The unique features of drought, however, do not foster the same hair-trigger response as more immediately compelling hazards like storms and floods. Unlike those other scenarios, prolonged drought provides time for an evolving response to crisis if planners and public officials are prepared to use that time well. This is the one rationale for the recent development of the drought tournament, initiated in Canada and reapplied in Colorado. This gaming forum challenges those involved to think more comprehensively and clearly about the consequences of drought and their communities' responses to it.

Bottom line: Training exercises and drought tournaments provide a crucial means of preparing public officials and planners for the eventuality of the real thing. Get some practice before the game starts.

Integrated Approach to Water Management

One of the early debates in the development of this project concerned the potential relevance of international case studies to the U.S. environment. Differing political systems often limit the transferability of the lessons of such case studies unless there is some core principle that holds true in spite of those differences. In choosing the case of the Murray-Darling basin in Australia, however, it became apparent that one overriding principle, which emerged more out of frustration and experience than from the system itself, was the need for a comprehensive approach to water management. This is not a lesson foreign to U.S. experience. A great deal of intergovernmental cooperation in the U.S. emerged from similar frustrations with fragmentation among competing levels and units of government.

Nature tends not to respect our political boundaries, many of which are quite arbitrary in nature. As a result, we are often challenged to examine our hazards through a larger prism than the one afforded by municipal, county, or even state government. It took Australia decades of planning and reforms to achieve a wider level of cooperation, but ultimately it has happened. Looking at the Australian experience in this regard affords us a certain analytical distance that is often hard to achieve closer to home.

Bottom line: Few of our political boundaries follow watershed lines, but effective water management often demands that our thinking surmount those boundaries and take in the whole problem. Planners are trained to think comprehensively and may have to apply those skills at a high level to deal with drought effectively.

Sharing Data and Tools with Stakeholders

Watersheds containing multiple actors in a system that places heavy burdens on water supplies must place a premium on open and transparent communication, particularly regarding the ways in which water supply projections and drought prediction work. Uncoordinated response to drought within a region can lead to serious problems in adequately managing a scarce resource. Faced with confusion resulting from widely varying local water-consumption restrictions, the Metropolitan Washington Council of Governments in 1999 formed a task force with a special emphasis on communication and coordination among the various stakeholders and water suppliers in the Potomac basin. Stakeholders are now trained in drought procedures, and the ICPRB is moving toward open-source programs to make its planning models more readily available to partner organizations.

Bottom line: Making data more transparent and widely shared among stakeholders, including training procedures to implement consistent drought policies, can enhance public support and reduce frustration among users and local water suppliers.

Diversification of the Water Supply

Florida may appear to have inexhaustible supplies of water. That is an illusion. The challenges of both sustained high population growth over half a century and periodic bouts of prolonged drought can put much of the state on the razor's edge under the right circumstances. Combine that with a history of inadequate coordination and cooperation among water providers, and the makings of a crisis were inherent in the system, producing intense competition for limited supplies. In addition to improving governance of water management, the Southwest Florida Water Management District and Tampa Bay Water had to ensure that they were not merely relying on over-pumped wellfields. The result was a master water plan to diversify the water supply for the region, with a new water-treatment plant, reservoir, and surface water sources, and in 2007 the area's first desalination plant, the largest in the U.S. to date. The new approach included significant water capture and conservation measures to reduce reliance on stressed groundwater sources.

Bottom line: Even in an area whose climate seems to ensure an ample water supply, stressors like population growth may require serious planning for alternative water supplies. The best way to achieve that is through effective regional collaboration.

Continuous Data Collection, Forecasting, and Monitoring

The CO-OP has learned to provide ongoing data collection and forecasting for the Potomac River basin, with updated water-demand forecasts every five years and longer-range forecasts over 20 years. In addition to these long-term forecasts, the CO-OP updates water supply outlooks on a monthly basis during the warmer half of the year, in part to stay on top of the potential for drought to tighten the region's water availability, as well as to anticipate needs for water releases from reservoirs and other adjustments to ensure adequate water supply.

Bottom line: Tracking water availability in relation to water demand is an ongoing responsibility that can leave a community or region better able to anticipate both short-term and long-term changes in the prognosis for drought and the challenges it may entail. This capability needs to be built into the water planning system.

LOOKING TO THE FUTURE: WHAT ELSE SHOULD COMMUNITIES DO TO MITIGATE DROUGHT?

This report has reviewed both standard tools for addressing needs for drought mitigation and preparedness and more advanced tools already at work in some of the communities highlighted in the case studies. Many of these tools serve their communities well under existing conditions. Now it must be said, even though the message is not popular in all quarters: We cannot expect conditions everywhere to remain the same. Climate change is real, and it will have real impacts on our water supplies and weather patterns over time. Communities that do not prepare to deal with this reality now may find themselves at a serious disadvantage in coming decades. Communities without reliable water supplies and effective management of those supplies may find themselves at a competitive disadvantage in an increasingly globalized economy. Businesses dependent on adequate water supplies may have to choose carefully where they locate, and jobs will be at stake. Planners must find a way to communicate such projections to both the public and decision makers. Planning and developing new water infrastructure to address such problems can take a long time, and time is often precious.

There is a paradox at work in some parts of the country (and the world) that may be difficult for many people to grasp: the possibility that climate change can simultaneously produce increased numbers of extreme precipitation events with flooding and an increased propensity for drought. Neither result is helpful for water management. In a recent presentation in Cedar Rapids, Professor William J. Gutowski, Jr., of Iowa State University's Department of Geological and Atmospheric Sciences, explained that higher average temperatures mean that the atmosphere can hold more moisture than it could previously (Gutowski 2013). The amount of humidity in the atmosphere at higher temperatures must be more than at lower temperatures to trigger precipitation. Therefore, while higher temperatures can result in larger storms, they can at the same time lead to prolonged drought if requisite moisture levels are not reached. In short, major parts of the U.S. may face the combined dilemma of more severe flooding and drought in their future. Are we prepared to confront such a paradox? Do our communities have the political will to face the new reality and adopt the long-term outlook needed to anticipate and adapt to such change?

That is probably still very much an open question, but it is one that demands some serious responses from both water planners and community planners working together to achieve forward-looking solutions. Planners by nature are expected to be focused on the future, and drought mitigation and water management are among the largest challenges facing the planning community. This report has sought to make the best known and most up-to-date tools more readily available to help solve those problems.

Glossary

Aridity Some regions are naturally dry, or arid. It is possible to have a drought in a desert, but it may be hard to detect without expertise and good knowledge of what the ecosystem looks like during normal years. In short, aridity is a permanent feature of a region's climate regime.

Carbon footprint The carbon footprint of a home or business is the amount of carbon released into the atmosphere due to burning of fossil fuels. Collectively reducing the societal carbon footprint is seen as a way to slow or reverse global warming.

Climate Climate is the statistical average of observed weather for any given scale. Without seeing a forecast, one can use climatological knowledge based on past observations to anticipate what conditions might be like at a particular place and time.

Climate change Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate variability Climate variability refers to the way climate fluctuates naturally (monthly, seasonally, annually, and even by decades, centuries, and millennia) in relation to a long-term average value. Water utilities and other aspects of urban living are designed to protect people from climate variability and typically do a good job. Drought is a normal result of climate variability.

Dissolved oxygen Dissolved oxygen refers to bubbles of gaseous oxygen that are in water and available to aquatic organisms for respiration. It is an indicator of water quality. Without oxygen, aquatic organisms cannot grow, feed, or reproduce effectively and may die.

Drought Drought is a natural part of virtually all climate regimes, including deserts and rain forests. Generally speaking, drought is a temporary precipitation departure from a region's average climate regime. However, it is important to note that there is no one definition for drought. In addition to the preceding conceptual definition, drought planners should adopt an operational definition based on their own circumstances. The chosen indicator(s) should help planners recognize a drought as soon as possible.

Drought emergency A drought emergency is usually declared by officials, typically factoring in political and human considerations as well as some threshold, or trigger, of water availability.

Drought Impact Reporter The Drought Impact Reporter (DIR) is a comprehensive, web-based archive of drought impacts reported by a variety of sources. It has been online since 2005 and is updated in near real-time from media, government, and individual observers' reports. The DIR is available at droughtreporter.unl.edu.

Drought mitigation Drought mitigation strategies include short- and long-term actions, programs, or policies implemented in advance of drought, or in its early stages, to reduce the degree of risk to people, property, and productive capacity.

Drought Management Database The Drought Management Database (DMD) is an actively curated collection of strategies that help reduce vulnerability to drought. Strategies come from the media, scholarly literature, and the informal network of the drought preparedness community of practice. The DMD is available at drought.unl.edu/droughtmanagement/Home.aspx.

Drought plan/planning A drought plan emphasizes that drought is a normal, recurring feature of climate and that planners and policymakers can and should protect people from drought impacts by planning for variability in the amount of water available. Many urban dwellers are well-insulated from drought by professional water utility management, but people dependent on wells or smaller water systems face higher risks, as do agricultural users and other sectors outside managed utilities. A drought response plan identifies actions to be taken during drought, such as maintaining a list of companies with trucks that can haul water. A drought mitigation plan identifies long-term actions to reduce vulnerability to drought.

Drought Risk Atlas The Drought Risk Atlas (DRA) is an online tool that compares historic droughts using data from individual climate stations. Assessing the drought "climatology" of an area is an important step in better understanding the frequency with which droughts of various severity levels can be expected, how droughts are a normal part of the climate system, and the importance of planning for drought. The DRA is available at droughtatlas.unl.edu.

Evapotranspiration During evapotranspiration, water leaves the surface of the earth either through evaporation or transpiration and enters the earth's atmosphere.

Flash drought A flash drought comes on very quickly, with heat often compounding dry conditions. It is usually a quick-onset event that evolves on the order of a few weeks to months, as opposed to several seasons or years.

Greenhouse gases Greenhouse gases are gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation of thermal infrared radiation emitted by the earth's surface, the atmosphere itself, and clouds. The main greenhouse gases are water vapor, carbon dioxide, nitrous oxide, methane, and ozone.

Hydraulic fracturing Hydraulic fracturing, also known as hydrofracking, uses water and chemicals forcefully injected underground to extract methane from rock formations. Many consider it to be an environmentally questionable process.

Hydrologic recharge This can refer either to water from the surface of the earth seeping into the ground and recharging aquifers, or water filling reservoirs, rivers, and streams. Impervious surfaces prevent water from percolating into the soil and accelerate runoff that may end up recharging reservoirs.

Hydrologic cycle The hydrologic cycle is the continuous movement of water above, below, and on the earth's surface.

Hydrozoning Hydrozoning involves grouping plants by water needs within a landscape. See xeriscaping.

InciWeb InciWeb provides compiled information about current and recent wildfires. The InciWeb site is located at www.inciweb.org.

Indicator, index, indices There are several different widely accepted ways to calculate and depict drought, including the U.S. Drought Monitor, the Palmer Drought Severity Index, and the Standardized Precipitation Index. For a detailed comparison of their pros and cons, see "The Comparison of Major Drought Indices" on the National Drought Mitigation Center's website at drought.unl.edu/Planning/Monitoring/ComparisonofIndicesIntro.aspx.

Local hazard mitigation plan State, tribal, and local governments are required to develop hazard mitigation plans as a condition for receiving certain types of nonemergency disaster assistance, including funding for mitigation projects. These plans identify the natural hazards (including drought) that impact communities, identify actions to reduce losses from those hazards, and establish coordinated processes to implement the plans. A community may develop its own plan or be part of a multijurisdictional plan.

National Drought Mitigation Center The National Drought Mitigation Center (NDMC), located at the University of Nebraska-Lincoln, helps people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management. The NDMC website is located at drought.unl.edu.

National Integrated Drought Information System The National Integrated Drought Information System (NIDIS) is a collaborative, interagency effort led by the National Oceanic and Atmospheric Administration (NOAA) aimed at improving the drought monitoring, planning, education, early warning, and forecasting capacity of the United States in order to prepare for and mitigate the effects of drought. The NIDIS website is located at drought.gov/drought/.

Paleoclimatology Paleoclimatology relies on proxy data such as tree rings, ice cores, or sediment samples to describe climate conditions prior to the historical record of measured precipitation and temperature.

Saltwater intrusion During drought, saltwater may travel both aboveground and belowground further inland than usual, disrupting freshwater aquatic ecosystems in coastal areas and contaminating freshwater aquifers.

Shrink-and-swell cycles Expansive soils such as those containing clay shrink when they are dry and swell when they are wet, which can damage building foundations and infrastructure, such as water pipes.

Teleconnection A teleconnection is a relationship between two distant weather events. The weather phenomenon El Niño, for example, has been linked to a wide variety of events, including wildfires in the Australian Outback, flooding in the Peruvian Andes, and above-normal rainfall in the Greater Horn of Africa.

Transpiration Transpiration is evaporation from a plant's leaves and other surfaces.

Urban heat island effect Sometimes cities are warmer than the surrounding countryside due to more reflective surfaces and higher concentrations of buildings and vehicles. The heat produced leads to what is called an urban heat island effect.

U.S. Drought Monitor The U.S. Drought Monitor is a map issued every Thursday showing the location and intensity of drought in the United States. It is based on numeric data, with gaps and discrepancies resolved by experts' best judgments and a nationwide network of more than 350 observers. The map is the product of a partnership between the NDMC, the U.S. Department of Agriculture, and NOAA. The U.S. Drought Monitor is available at droughtmonitor.unl.edu.

Water budget Water is a finite renewable resource. Some water planners think in terms of water budgets—the allocation of water to various uses within the constraints of available supplies.

Water footprint A water footprint is the total amount of water used by a household, business, industry, or other user. A subdivision or site can reduce its water footprint by encouraging xeriscaping.

Water conservation ordinance A water conservation ordinance is a policy aimed at reducing water consumption. An ordinance could require, for example, water-efficient fixtures in new buildings, or water restrictions during the summer or when drought occurs. Failure to abide by the ordinance will usually result in a fine or other sanction.

Water conservation plan A water conservation plan is a group of policies that outlines a community's strategy for achieving a reduction in water loss, waste, or use. These could include long-term permanent reductions or relatively short-term reductions.

Xeriscaping Xeriscaping, or nativescaping, is landscaping that uses native plants with lower water requirements than exotic vegetation and turfgrass. The stereotypical image is gravel and cacti instead of turf, but xeriscaping also includes attractive, colorful native plantings grouped by the amount of water needed or smaller lawns.

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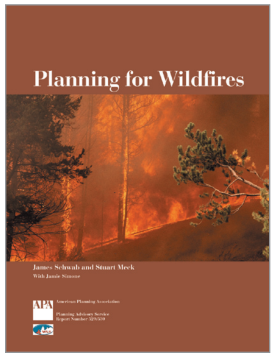

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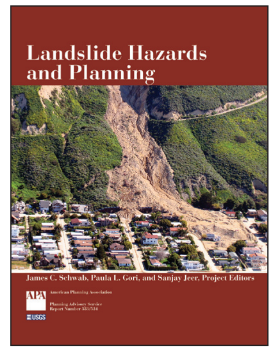
PAS 529/530. James Schwab and Stuart Meck. 2005. 124 pp. $15.

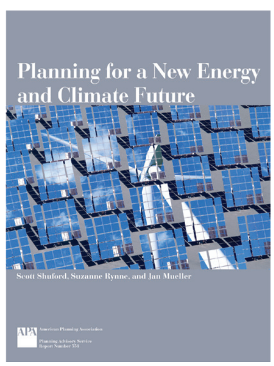
Wildfires are both dangerous and costly, yet people continue to build in wildfire-prone areas. This poses challenges for governments and planners, who must decide whether to permit development in such areas and how best to design developments that are allowed. This report explores both issues, outlining how knowledge of wildfire risks can be incorporated into comprehensive planning and identifying best practices for development in at-risk areas.

Landslide Hazards and Planning



PAS 533/534. James C. Schwab, Paula L. Gori, and Sanjay Jeer (eds.). 2005. 208 pp. $15.

Is a landslide waiting to happen in your community? Landslides occur primarily in mountainous regions, but flatter parts of the country are not immune. Landslides often go hand-in-hand with other natural disasters such as wildfires and floods, making them an important consideration in hazard mitigation planning and comprehensive plans. This PAS Report offers basic knowledge of the natural and manmade factors that trigger landslides, as well as information needed to identify at-risk areas and determine whether development should be permitted. The report also explains remedial tactics for landslide areas where development already exists and regulatory tools for preventing development or ensuring the safest possible development.



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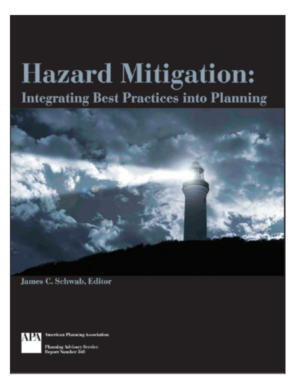
PAS 558. Scott Shuford, Suzanne Rynne, and Jan Mueller. 2010. 160 pp. $60.

Planners have an important role to play in helping communities meet energy needs, reduce greenhouse gas emissions, and adapt to a changing climate. This PAS Report presents fundamental information about energy and climate change, provides a framework for how to integrate energy and climate into the planning process, and offers strategies for communities to address energy and climate across a variety of issues, including development patterns, transportation, and economic development. Case studies illustrate communities that have already begun taking steps in these areas.

Hazard Mitigation: Integrating Best Practices into Planning



PAS 560. James C. Schwab (ed.). 2010. 152 pp. $60.

Every year, communities face natural hazards—floods, wildfires, landslides, earthquakes—that can cause millions of dollars in property damage. Well-crafted plans, policies, and land-use regulations can help mitigate the impacts of natural disasters—but in many communities today, planners have either limited involvement in hazard mitigation plans or none at all. This report introduces hazard mitigation as a vital area of practice for planners; provides guidance on how to integrate hazard mitigation strategies into comprehensive, area, and functional plans; and shows where hazard mitigation can fit into zoning and subdivision codes.

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