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Drought and Health in the Context of Public Engagement

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Drought and Health in the Context of Public Engagement

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Abstract
Droughts have profoundly affected societies around the world from the earliest beginnings. A recent estimate from the Centre for Research on the Epidemiology of Disasters (CRED) claims that more than 1 billion people have been affected by drought during the twenty-year period between 1994 and 2013. Because of the characteristics of drought, drought impacts are often difficult to identify and quantify, and this is especially true with public health-oriented drought consequences, including those resulting from low water quantities, poor water quality, mental health and stress, dust and windblown agents, and wildlife intrusion. However, when officials emphasize adopting a proactive risk management approach to address drought, opportunities increase for reducing future public health risks. This chapter provides an overview of drought and describes drought risk management. The chapter ends with several case studies illustrating how public engagement can greatly assist in preparing a region for future droughts. Preparedness for drought is important as the competition for valuable and finite water resources increases, and as climate change potentially increases drought frequency and severity.

Keywords: Drought, Health, Engagement, Impacts, Risk, Management

1 Introduction

In 2013, as Brazil prepared to host the 2014 FIFA World Cup, a drought began to develop that targeted the heavily populated southeastern part of the country, which includes São Paulo and Rio de Janeiro, Brazil's biggest metropolitan

regions. The World Cup came and went, but the drought did not. Reservoirs for the largest of several São Paulo water systems, servicing a population of at least 20 million, shrank to just 5% of capacity by February 2015. One report estimated that São Paulo had four to six months of water remaining and was "on the edge of an unprecedented public calamity" (Whately and Lerer 2015, p. 4). As the drought continues, the public health impacts are potentially enormous, and some of these impacts, related to both low water quantity and poor water quality, are already being felt in many impoverished neighborhoods. Officials are scrambling for solutions even as the next big global event hosted by Brazil, the 2016 Summer Olympics in Rio de Janeiro, looms. Meanwhile, observers around the world watch what is happening in São Paulo with keen interest, wondering whether São Paulo is now a prototype for their future. Other recent droughts around the world have provided dramatic examples of the serious and widespread nature of possible public health impacts caused by drought events. In California, the current multiple-year drought is affecting public health in a variety of ways; increased hunger, increased stress, dry homeowner wells and poor air quality from parched forests and wildfires are just a subset of these health-related impacts. The droughts in 2011 and 2012 over large agriculturally productive regions in the United States illustrate how droughts can have major economic impacts within developed nations, as well as affecting food security and global agricultural markets.

In 2010, the drought and heat wave across Russia's wheat belt served as an important reminder that any event negatively affecting the production in an important agricultural region has worldwide ramifications related to food security. Likewise, the 2011 drought in eastern Africa demonstrated how droughts occurring in developing nations, where food costs can easily consume more than 50% of family incomes, can also have serious consequences. Finally, the drought event in southern Brazil highlights how droughts can potentially threaten the water supplies of major metropolitan areas even in regions where droughts are not necessarily considered a serious problem.

Reducing future drought risks related to public health impacts will rely on proactive risk management. This chapter investigates the relationships between drought and health in the context of public engagement activities, and how public engagement activities build resilience and potentially reduce future public health risks resulting from droughts.

2 What Is Drought?

Drought is a natural hazard similar to several of the extreme events highlighted within this book. The Centre for Research on the Epidemiology of Disasters (CRED 2015) recently reported that there have been 6873 natural disaster events worldwide between 1994 and 2013. Of these events, 322 were droughts, and CRED estimates that they affected 1.1 billion people. In the United States, as in most locations around the world, droughts are considered a normal part

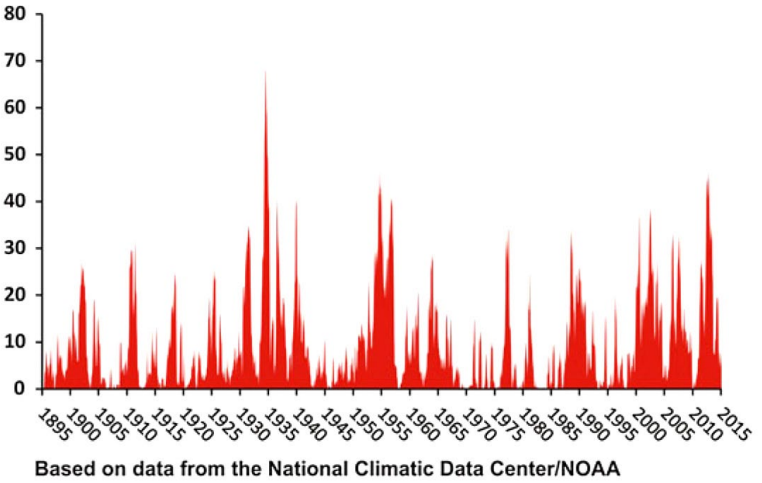

Fig. 1. Percent area of the U.S. in severe to extreme drought (January 1895–February 2015).

Table 1. Billion-dollar droughts (loss/cost estimates normalized to 2012 U.S. dollars using an inflation index) (National Centers for Environmental Information 2015)

Year	States affected	Loss/cost estimate billion
2012	Midwest	>$40
2011	Southern plains	$12.2
2009	Southwest and southern plains	$5.4
2007	Southeast, Ohio Valley, Great Lakes	$5.6
2006	Great Plains, South and West	$6.8
2005	Midwest	$1.2
2002	Western states, Great Plains and much of the eastern U.S.	$12.8
2000	South-central and southeastern U.S.	$5.3
1999	Eastern U.S.	$1.4
1998	Oklahoma/Texas eastward to the Carolinas	$10.6
1996	U.S. southern plains	$7.3
1993	Southeastern U.S.	$1.6
1989	Much of the northern plains	$1.9
1988	Central and eastern U.S.	$77.6

of climate. Figure 1 shows that severe and extreme drought occurs somewhere in the country in almost every year going back to 1895. Table 1 lists the economic loss estimates for recent droughts that have hit the U.S. This table does not include the most recent impacts occurring in California. Estimates from California appear to have the drought losses in the $6 billion range, but climbing as the drought continues.

The unique characteristics of drought, however, cause it to be different from many of the other natural hazards. Gillette (1950) described droughts as "creeping phenomena" because droughts can often develop very slowly over a long period of time, and officials may not recognize that they are in a drought situation until months, or even years, have passed. It can be very easy for everyone to focus on the promise of expected rains during the upcoming weekend or the upcoming rainy season. This natural wait-and-see perspective adds to the challenge of making timely responses in the middle of a drought event. Tannehill (1947) described a second characteristic of droughts that challenge officials dealing with drought events: unlike other natural hazards, droughts do not have a clear, quantitative definition. Rather, droughts are specific to the sources and uses of water in each location and the expectations for that water, which varies widely, even in small spatial regions. Finally, Wilhite and Buchanan-Smith (2005) pointed out that because droughts lack the dramatic visual impacts of other natural hazard events, drought events could escape the attention of the media, public, and officials, contributing to the challenges of a timely response to a drought event until the impacts are often very severe. This is very different from the dramatic photos or videos of tornadoes, floods, tropical cyclones, and other natural hazards.

Given the complexity of drought and its characteristics, it can be useful to consider droughts according to disciplinary perspective. Four perspectives were originally described by Wilhite and Glantz (1985): meteorological, agricultural, hydrological, and socio-economic. The meteorological perspective relates to the precipitation deficit from an expected amount, often measured using a variety of indicators and indices. The relationship between plant water demands and the amount of available water, particularly within the soil environment, best describes the agricultural drought perspective. A hydrological drought perspective highlights longer-term impacts on the hydrological resources of a region such as stream flows, reservoir levels, snowpack, and groundwater. Socioeconomic droughts involve societal or environmental impacts that occur as a result of meteorological, agricultural, or hydrological droughts. Figure 2 is an idealized view representing the timing in each perspective. In reality, however, these four perspectives often overlap. A good example of overlap is how agricultural production that is dependent on irrigation can be affected by a hydrological drought that is affecting the water resources of a region—at the same time the region is not necessarily experiencing much of a meteorological drought.

3 Drought Impacts

Droughts are often dismissed or overlooked because they are identified as a hazard mainly associated with agricultural impacts, which in turn affect the livelihoods of relatively few people within a specific region. Or they may capture attention because they contribute to humanitarian crises in developing nations. Recent droughts, however, show the increasing connection between droughts

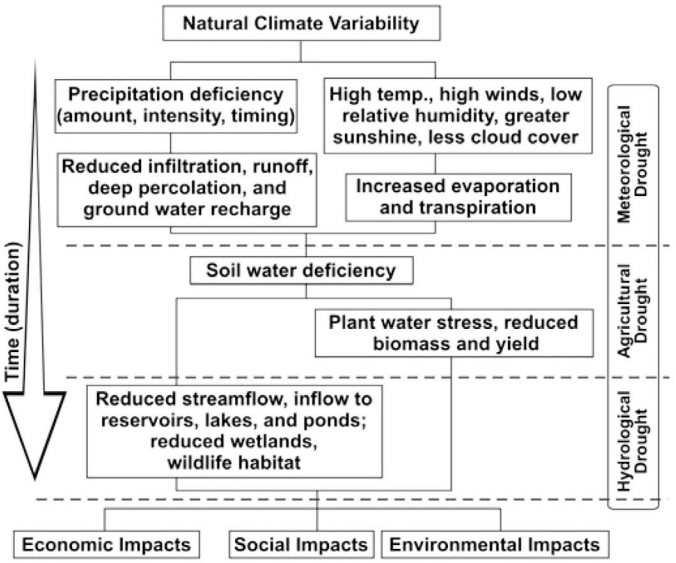

Fig. 2. The disciplinary aspects of drought. Source National Drought Mitigation Center, University of Nebraska-Lincoln, http://www.drought.unl.edu/DroughtBasics/TypesofDrought.aspx

and food security around the world as a result of global markets and international trade. In addition, recent droughts also show that drought impacts are growing in complexity beyond the agricultural sector as the demands for water grow and the potential competition for dwindling water resources also grows. In the United States, for example, impacts on urban water supplies, energy production, recreation, tourism, ecosystems, transportation, wildfires, and public health have all occurred in recent droughts. Because vulnerabilities to drought vary according to location, drought impacts will also vary by location. Just a few of the factors influencing an area's vulnerability to drought include poverty levels, urbanization, population densities, and land use practices.

For public health, the consequences of drought can be organized into four categories: (1) water quality and water quantity, (2) mental health and stress, (3) dust and windblown agents, and (4) wildlife intrusion. Specific examples for each category will be described but, as mentioned above, overlap between the categories is common.

3.1 Water Quality and Water Quantity Impacts

Good health relies on good water quantity and water quality. Therefore, when droughts affect either or both of these aspects, public health impacts are possible (Stanke et al. 2013). When droughts occur, the first health-related consequences

likely relate to water quantity. It is true that in developing nations, droughts can threaten both food and water security directly. The lack of available food can lead to malnutrition and mortality, as well as to listlessness and an increased susceptibility to disease. When combined with governmental breakdowns or strife, drought events can be a contributor to wide-scale famines. Likewise, the decreased availability of basic drinking water supplies for the local populations in developing nations also puts pressure on the health of those populations. The lack of food, water, or both also causes the migration of people, which creates additional public health issues, both during the migration and at the end destinations because of increased crowds and often unsanitary conditions.

Water quantity issues affecting public health are less common in developed nations, but they have been seen in the U.S., for example, when homeowner wells go dry, limiting that source of water supply for those individuals, particularly in rural areas. In these cases, it is often not the direct cause for human mortality or morbidity, as in developing nations, but health-related problems related to the physical toll on the body hauling water. As one example, the U.S. Environmental Protection Agency (U.S. EPA) (2015) estimates that 2.3 million people in New England (approximately 20 % of the population) get their drinking water from private wells. As a result of a severe drought in Maine during 2001–2002, the governor asked for a presidential disaster declaration for the state, largely because of the public health impacts stemming from dry private wells. In his letter to then-President George W. Bush, Governor King (2002) estimated that 2300 families were without running water, and another 18,400 families had well supplies that were threatened. The governor's request was unsuccessful. The only presidential disaster declaration for drought issued to date was for Guam during a drought in 1998, because of the lack of drinking water supplies on that island.

Because these impacts are much less obvious and are frequently overlooked, public health-related risks caused by reduced water quality and low water quantity are often closely linked during drought events. These types of impacts can occur in many locations around the world and in both developed and developing nations. As groundwater levels and hydrological supplies in streams, lakes, and reservoirs decrease, the potential goes up for increased water temperatures and increased levels of harmful chemicals. This can lead to increased salinity and reduced oxygen levels within the water, threatening aquatic species (Bond et al. 2008). Fish kills tend to be a frequently reported drought impact. Less frequently, it is noted that reduced water quality and quantity during drought events increase the need for water treatment where that capacity exists. Increased concentrations of toxins and pollutants may result from industrial and sewage wastewater discharges that would otherwise be at safer concentrations, diluted with normal quantity water levels. These water quality/quantity effects can be detrimental to the health of both humans and the environment. Reduced water quality also results in more water-borne disease outbreaks such as cholera and E. coli (Stanke et al. 2013).

In the U.S., another drought-related public health problem is seen during and after wildfires, particularly in the western part of the country. Wildfires

expose watersheds to ash, erosion, and debris that can seriously affect water systems within those watersheds. In 2002, the Arizona Republic noted that "ash and debris from the 'Rodeo' fire flowed down the Salt River into Roosevelt Lake ... turning the river black with contaminants that could kill the fish in the reservoir and leave it lifeless for months" (McKinnon 2002, p. A1). Following the 2002 Hayman Fire in Colorado, Denver Water sent a notice to customers in one of the watersheds important for Denver's water supply that said "the water runoff...may cause your water to have a smoky/ashy, moldy, dirty, musty, earthy, maybe even astringent taste" (Hayes 2002, p. 223). These two examples illustrate the potential public health impacts droughts and wildfires can have on water quality.

Both water quantity and water quality affect public health indirectly on water-related recreation. Low water hazards can contribute to boating and swimming accidents. Poor water quality can affect recreational activities, closing beaches because of high levels of chemical concentrations or algae. In Nebraska, high concentrations of cyanobacteria in local lakes caused by low water levels have caused a variety of public health impacts.

3.2 Mental Health and Stress Impacts

Drought can also affect mental health. These impacts are difficult to quantify and are not well understood, but there is a growing effort to acknowledge what droughts bring to stress and mental health. Often these effects appear across agricultural communities where potential drought consequences for agricultural production can create stress in families, which in turn can affect physical health, lead to nutritional problems, and cause depression, domestic violence, substance abuse, and suicides. Studies in Australia have linked drought with suicide in rural regions (Guiney 2012; Hanigan et al. 2012).

The effects of drought on mental health and stress can extend beyond the agricultural community, especially where business-related financial pressures caused by drought may occur. In the U.S., the need to haul water into homes because wells went dry caused the same increases in stress-related impacts seen within agricultural regions. It is important to consider how mental health and stress vary between men, woman, children, and the elderly, and between more affluent and poor populations. In one review of the literature of drought-related mental health and stress on children (Stanke et al. 2013), the common themes were related to "worry about family" and "feelings of loss."

3.3 Dust and Windblown Agents

Droughts contribute to airborne dust and windblown agents, and this, in turn, can have a very significant effect on public health. An iconic example of this occurred during the dust storms of the 1930s "Dust Bowl" drought in the central

United States (Sarafoglu and Sprigg 2015). Dust storms still occur, mainly in arid and semi-arid regions around the world. But the incidence of these dust storms increases during drought events, where vegetation recedes and bare ground is exposed, and can impact regions far downwind from the origins of the dust. The harmful effects of dust occur from either the direct trauma of inhaled particulates or by pathogen carriage, influencing the incidents of respiratory, heart, and lung diseases (Sprigg et al. 2012; Stanke et al. 2013). Sprigg et al. (2014) and Stanke et al. (2013) indicate that incidents of Valley Fever in the western United States are associated with the linkages between drought, environmental events, and the responsible fungus spores being carried by wind events.

Like dust, smoke from wildfires can cause significant respiratory problems. Older adults, children, pregnant women, and people with asthma, heart, and lung diseases are particularly vulnerable to smoke, which is comprised of a complex mixture of gases and particulates. The effects of smoke can be from a local wildfire, or the smoke might be carried hundreds of miles downwind from a wildfire event. In the U.S., the number of people with asthma is about 25 million, or about 1 in every 12 people. This number is growing, and it illustrates why more research on the linkages between droughts and public health is needed.

3.4 Wildlife Intrusion

Some of the more commonly reported public health consequences of drought are those that result from increased interactions between wildlife and humans. In recent years, these interactions have included large predators such as bears and mountain lions wandering into urban areas in search of water and food, increased car-animal accidents, increased numbers of snakes and alligators in urban ponds and lakes, and increased spider bites. Animals may also carry various diseases, so increased interactions between humans and wildlife can lead to more disease outbreaks.

The relationship between droughts and mosquito populations, and thus mosquito-borne diseases, is also complex. One might speculate that mosquito populations would decrease during drought events, thus reducing the number of people infected by mosquito-borne diseases. But the interactions between mosquitos, drought, and local environmental factors may actually increase diseases such as Dengue, several encephalitis viruses, West Nile Virus, and Rift Valley Fever Virus (Stanke et al. 2013). It is unknown how drought might affect malaria occurrences.

4 Drought Risk Management

Traditionally, most attention on drought events has focused on how to respond to the consequences as the drought unfolds. This has been true regardless of where droughts have taken place. This reactive approach is "crisis management." Given the characteristics of drought, it is not surprising that crisis

management-oriented responses to drought have often been uncoordinated and untimely (GSA 2007; Wilhite and Pulwarty 2005). In addition, when the attention is focused only on crisis management, the capacity to reduce future drought impacts is limited. On the other hand, a paradigm that focuses on drought risk management attempts to reduce future impacts by improving drought monitoring, planning, and mitigation strategies (Wilhite et al. 2005). This risk management approach is inherently proactive and directed at identifying who and what is at risk, why they are at risk, and how individuals can prepare for and respond to events. In the United States, the National Drought Policy Commission made recommendations in a report submitted to the U. S. Congress (NDPC 2000) that emphasized the Nation's need to focus on risk management, preparedness, and mitigation, including a more comprehensive drought monitoring system. Although the progress of drought risk management around the world has been slow, Wilhite et al. (2005) point out some successes, such as the High-Level Meeting on National Drought Policy (HMNDP), hosted in 2013 by the World Meteorological Organization in Geneva, Switzerland. Country representatives from 92 nations unanimously supported a declaration encouraging countries to develop and implement proactive national policies focused on drought risk management. The Integrated Drought Management Programme, co-led by the World Meteorological Organization and the Global Water Partnership, was then launched to assist.

The concept of drought risk management is illustrated in Fig. 3, the Cycle of Disaster Management. This cycle applies to all natural hazards, which is why some components of the crisis management part of the cycle (such as "reconstruction") work better for hazards such as floods and tropical cyclones. The bottom half of the cycle, representing crisis management, will always be necessary in some form in order to respond to the impacts of a current drought event. However, Fig. 3 highlights that actions of monitoring and early warning,

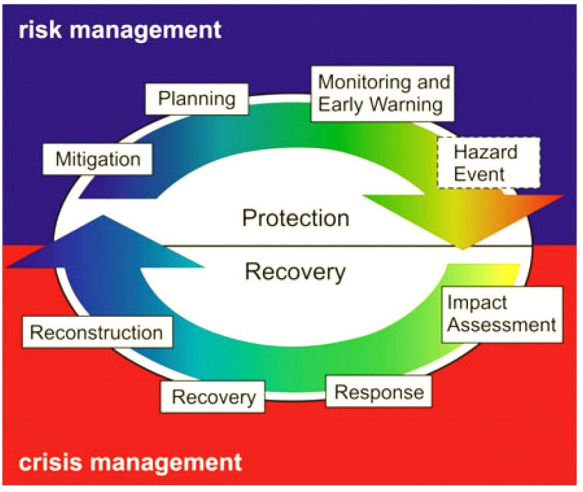

Fig. 3. The National Drought Mitigation Center's cycle of risk management versus crisis management. Source National Drought Mitigation Center, University of Nebraska-Lincoln.

planning, and mitigation must take place before future drought events occur in order to reduce the impacts of these future events. These components of the cycle are considered drought risk management.

Drought monitoring involves continuous assessment and anticipation of the natural indicators of drought severity, spatial extent, and impacts. Using this information to encourage response is called "early warning." Decision makers require accurate early warning information to implement effective drought response activities, recovery programs, and proactive drought policies. Early warning, then, is essential for drought risk management. Early warning connects risk and crisis management (Wilhite and Buchanan-Smith 2005).

When officials engage in drought planning, the second component of drought risk management, the objective is to reduce the impacts of drought by identifying the principal activities, groups, or regions most at risk and developing strategic actions and programs that address these risks, as well as response actions that can be taken during a drought event. Drought plans provide an effective and systematic means to assess drought conditions, identify who and what is at risk to drought events, develop mitigation strategies that reduce risk in advance of drought, and devise response options that minimize economic stress, environmental losses, and social hardships during drought. This overall emphasis on drought planning is fundamental to drought risk management and is applicable at any decision-making level. Incorporating drought planning helps decision makers prepare for multiple hazards, including climate change, and will promote sustainability and natural resource management leading to greater economic and societal security at all levels (GSA 2007). Benefits of drought planning across the United States include improved drought monitoring systems and the delivery of this information to decision makers at all levels. Benefits also include better identification of the risks associated with droughts, improved interactions with stakeholders, improved public awareness of drought, and protection of water resources during periods of shortage (Wilhite et al. 2005).

The third component of drought risk management is the implementation of appropriate drought mitigation strategies. These are specific activities prior to a drought that reduce the long-term vulnerability to droughts. In a study funded by the U.S. Federal Emergency Management Agency (FEMA), the Multihazard Mitigation Council (2005) calculated that a dollar spent by FEMA on earthquake, wind, and flood hazard mitigation provides the nation about $4 in future benefits. Besides the fact that hazard mitigation is a good investment, the Council concluded that continuing analysis of the effectiveness of mitigation activities is essential for building communities resilient to all hazards. This is especially true for drought, which was estimated by FEMA in 1995 to cause more annual economic losses in the United States than any other natural hazard. According to the United Nations International Strategy for Disaster Reduction (2007), the number of methodologies is limited for identifying appropriate drought risk reduction strategies. They concluded, "…it is essential to identify and demonstrate effective approaches and opportunities for drought mitigation and preparedness, including case studies to show examples of good as well as weak policies. Policy makers, scientists, media, and the public often need to

see actions-at-work in order to foster buy-into similar efforts" (ISDR 2007, p. 50). Identifying and promoting drought mitigation and preparedness has been part of the National Drought Mitigation Center's (NDMC, http://drought.unl.edu) mission since it was founded in 1995 and is also a key goal of NOAA's National Integrated Drought Information System (NIDIS, http:// drought.gov).

The NDMC has been involved in a few drought mitigation efforts related to public health. The first was participation in a Centers for Disease Control and Prevention (CDC) workshop in 2009 that led to the publication of the manual, "When Every Drop Counts: Protecting Public Health during Drought Conditions: A guide for public health professionals" (CDC et al. 2010). The NDMC assisted in editing this guide. The second was the launch of the Drought Impact Reporter in 2005 as the nation's first (and only) tool to collect, catalog, and display impacts occurring in ten different sectors, providing decision makers with readily summarized information. One of the ten sectors includes society and public health information. Finally, the NDMC recently launched another tool, the U.S. Drought Management Database Portal, which is a database of mitigation strategies by sector. One of the sectors included within this tool is society and public health.

5 Droughts and Climate Change

Droughts have always affected humans and are featured in many of the earliest documents, such as the tale of Joseph and Pharaoh in the Bible (Le Treut et al. 2007). Although Fig. 1 emphasizes the normal nature of drought, the looming effect of climate change threatens to alter the dynamics between drought and society, adding more stress and potentially increasing future public health consequences.

It is often said that the best way to understand the future is by understanding the past. Much attention has been given to developing an understanding of past drought events using tree ring data and other paleoclimatology records. Although certainly not diminishing the importance of these paleoclimatological studies, Milly et al. (2008) argue that past climatic conditions may not provide the best representation of the future because of climate change. Droughts around the world will be a factor of any precipitation and temperature change that might occur. The latest temperature projections from the IPCC (2014) indicate that global temperatures will likely increase between 1.1 and 4.8 °C by 2100, depending upon global greenhouse gas policies. Although projections of precipitation are not uniform and have a higher uncertainty in both spatial and temporal scales, it is very likely that extreme precipitation events will increase, particularly in the mid-latitudes (IPCC 2014).

The frequency of some climate-related extreme events is anticipated to increase, which has been supported by recent trends. Since 2000, the number of global climate-related disasters per year is 341. This number is up 44 % and more than 100 % from the 1994 to 2000 and 1980 to 1989 averages, respectively (CRED 2015). For droughts, even if precipitation amounts remain the same or

increase somewhat, higher temperatures just about everywhere mean that there will be increased evapotranspiration, meaning more moisture will be lost from both vegetation and soil surfaces. This expected outcome leads to the projection that droughts will increase in frequency and severity. Several other issues are factored into these projections, including the timing of rainfall and the fact that drying soil surfaces exacerbate heat wave events. In addition, projected reductions in runoff from winter snowpack would also reduce water availability.

Many public health challenges remain for addressing drought, given that droughts are a normal part of a variable climate, and that the trends of climate may be making droughts more frequent and severe. Daniel Connell of the Australian National University recently recognized this challenge, saying that drought was a "force of truth" for Australia, and other nations, in that if proactive drought risk management approaches were taken, these could reveal important insights into how to better prepare for climate change (Connell 2010).

6 Engagement Strategies

The International Association of Public Participation (IAP2) uses the slogan, "Good public participation results in better decisions" (http://iap2.site-ym.com/). It is relevant because a key ingredient for successful drought risk management is to incorporate opportunities for public engagement or public participation within the risk management process. The IAP2 presents a helpful spectrum for professionals to use where certain levels of public engagement need to be identified with stakeholders (IAP2 2015). Public participation is more than just involving the public, but rather taking the needed time to discuss and plan how certain decisions, such as research or outreach outcomes, might affect the decision-making process. It requires meaningful objectives and goals in order to provide materials and information that can be communicated so stakeholders can see, from the message, the potential consequences. In general, the practice of public participation might involve numerous techniques (e.g. workshops, surveys, focus groups). Some of these techniques are discussed in more detail in this section and in the subsequent engagement case studies.

The faculty and specialists at the NDMC have worked closely with this IAP2 spectrum model to help plan outreach strategies, including recent efforts in the drought and public health sector. The spectrum encourages practitioners to identify objectives for engagement and stakeholders early, in order to find the most beneficial techniques. The five levels of the spectrum include: Inform, Involve, Consult, Collaborate, and Empower. The NDMC has engaged stakeholders in at least four of the spectrum levels. The fifth level of empowerment is sometimes hard to quantify as it takes careful evaluation after the project or event to know if the information or process has made a significant impact in a stakeholder's decision-making. Again, by carefully planning a project's objectives, proper and effective techniques can be used to gain some of the techniques that the NDMC has used to engage stakeholders, including newsletters

Fig. 4. Stakeholders engaged in reviewing past drought impacts on their urban water supply system. Photo courtesy of Nicole Wall, National Drought Mitigation Center, University of Nebraska-Lincoln.

and online decision support tools such as the Drought Risk Atlas and Drought Impact Reporter. Workshops, webinars, focus groups, interviews, and surveys are other techniques. In workshops, the NDMC will include participation techniques such as polling, decision grids, World Cafés, and collecting feedback on a public participation "sticky" wall (Fig. 4).

As an example of collaboration and engagement, the NDMC partnered with the University of Nebraska Public Policy Center and others on a National Science Foundation project to conduct a series of educational presentations and focus groups in the fall and spring of 2011 and 2012 in Nebraska about drought and climate change. Six focus groups targeted 121 rural educators, agricultural producers, and the general public in Nebraska to assess knowledge and attitudes about drought and climate change and to identify needs for education. Using a pre-post survey design, focus group participants found that their knowledge, as well as their concerns, of key climate change issues increased significantly following the educational presentations by the project team. These findings suggest that rural communities in Nebraska are concerned about the effects of drought and climate change, and their understanding and attitudes of these issues can change with education and engagement.

Surveys have been conducted in rural Nebraska communities gauging perceptions and attitudes about drought (Allen et al. 2004) and climate change (Vogt et al. 2008). Comprehensive survey efforts, such as the annual Nebraska Behavioral Risk Factor Surveillance System survey (Nebraska Department of Health and Human Services 2013), have been undertaken to gather information on health experiences and behavior among Nebraskans. However, none focused

on the human health impacts of drought. Efforts to identify health/climate data collection among the state's agricultural and rural communities were unsuccessful. New proposals for research and outreach are being developed to meet these gaps between drought and human health.

The National Drought Mitigation Center, working with stakeholders, has adapted a variety of public engagement strategies that can be applied to public health outreach, especially in the area of climate change. Since drought spans many different sectors, it is important to think of a holistic, systems approach in public engagement efforts. Because of the complexity of drought impacts, impact and risk assessment must be interdisciplinary. It is essential to bring together the right group of people and supply them with adequate data to make fair, efficient, and informed decisions pertaining to drought risk. This group's knowledge must encompass several aspects of environmental, economic, and social topics. Any shortfall in information or perspective could lead to meaningless or at least questionable results.

6.1 Community Capitals Framework

Another key ingredient for successful drought risk management is to incorporate opportunities for public engagement in the drought planning process. Careful examination reveals that drought vulnerability varies significantly from location to location based upon local resources and characteristics. Therefore, public engagement is needed to build local resilience. This is certainly true when looking at the public health-related consequences of drought. Communities can benefit from previous experiences ("lessons learned") as they begin to address their own mitigation and adaptation strategies. The lessons learned can also help find gaps and barriers that need to be addressed before the next drought occurs. One way to integrate innovative techniques of public engagement in drought planning is by evaluating local drought impacts and discussing them in a context of the holistic community system such as the Community Capitals Framework (CCF) model (Fig. 5).

For instance, research into the factors and dynamics that influence community development and change demonstrate that communities that use and build across their natural (e.g., water), cultural (e.g., values), human (e.g., skills), social (e.g., social networks), political (e.g., ability to influence decisions), financial, and built (infrastructure) capital are generally more economically sustainable (Flora et al. 2004; Emery and Flora 2006). Thus, drought can cause devastating impacts to the very things that are essential for community economic sustainability and growth. Knowing more about the dynamics of the social, economic, and environmental factors that underlie communities, allows NDMC's collaborative research to promote sustainable and resilient communities by helping them identify, protect, and leverage a variety of community resources.

Fig. 5. Community capitals framework model. Source National Drought Mitigation Center, University of Nebraska-Lincoln, adapted from Flora and Flora 2004.

6.2 Drought Scenario Exercises and Tournaments

The importance of games in education is not new, and recently the importance of games in learning has been categorized as essential. Scientifically, it has been proven good for brain-nerve stimulation and long-term knowledge storage as it creates a "flow state" where learning is enticing because the various game levels require participants at any age to feel challenged but not defeated. Goal-oriented games are also important in the learning process, especially in stimulating creativity. Over the past several years, the NDMC has been involved in several water and drought tournaments and exercises. The Invitational Drought Tournament (IDT), originally created by Agriculture and Agri-Food Canada, has been the template in many of these interactions (Hill et al. 2014). The main goal of this engagement strategy includes building capacity around drought preparedness. The tournament helps a variety of stakeholders identify gaps and vulnerabilities surrounding drought preparedness and mitigation.

The game provides a face-to-face forum for multi-disciplinary stakeholders to discuss climate preparedness and adaptation strategies (e.g., such as those in public health) in a learning environment. The end result is a complete and traceable decision-making process that is based in goal-centered, real-life data

scenarios that involve creativity and collaboration. Today's technology lends itself to this interactive and social learning, which is a perfect platform for public health professionals. Tournaments and exercises incorporate a water budget and are utilized in a variety of settings to emphasize the trade-offs, complexities, and interconnectedness of water use decisions during drought and under various water availability scenarios. Target audiences for the game activities have been elementary, middle school, and college students, as well as local, national, and international stakeholder groups. Participants are placed into multidisciplinary teams that are then guided through a multi-year drought scenario of unknown length, throughout which they work collaboratively to discuss and select adaptation options that will help them better prepare for, adapt to, respond to, and recover from the drought's impacts. The curriculum can be expanded to incorporate evolving game theory and drought- and natural and water resource-related exercises developed for those involved in public health. The products of any tournament can be packaged as a set of online/electronic materials, and the final modules can be transferred to international partners as well.

This chapter concludes with three case studies highlighting how public engagement strategies can address potential public health impacts in the context of drought and climate change risk management.

7 Case Study: Greater Horn of Africa

Africa has seen multiple public health crises related to drought events throughout history. The latest data from CRED (2015) indicate that 41 % of the drought disasters since 1993 around the world have occurred in Africa. In addition to being vulnerable to droughts, Africa will probably be highly vulnerable to the projected adverse impacts of climate change resulting from increased temperatures, changes in precipitation, and increased climate variability. In many regions of the continent, the effects of these changes are compounded by rapid population growth, high poverty levels, social unrest, dependence on rain-fed agriculture, and low adaptive capacity. Given the great uncertainty in climate projections, early warning systems that are robust to evolving climate conditions must be a critical component of successful adaptation and mitigation strategies. Improved performance and application of seasonal forecasts is a critical, no-regrets climate adaptation strategy (Tadesse et al. 2014). But in many parts of the world, forecast systems perform poorly, forecasts are not always tied to user needs, and systematic forecast evaluation and comparison is lacking. In addition, there is a need to understand how forecasts influence the outcomes they are designed to predict. Experts and decision makers often have many challenges in understanding prediction models and products, interpreting model differences, and implementing those model products for societal benefits (including benefits for public health preparedness).

In 2014, the NDMC began a multi-institution collaborative project, funded by NASA, designed to enhance preparedness for extreme climate events (droughts and floods) and anticipated climate change impacts over the Greater Horn of Africa

(GHA). This project's objective is to improve and implement new and existing climate- and remote sensing-based agricultural, meteorological, and hydrologic drought and flood monitoring products (or indicators) and improve the usability of these products among various decision makers across the region. Recognizing that engagement strategies and theories of participatory research are important to achieve the objectives and improve decision making, the project incorporated a stakeholder engagement component from the beginning. The stakeholders include participants from a variety of sectors, including public health, and the expectation is that they will be involved in the project for its three-year duration.

The first workshop for the project was held in Addis Ababa, Ethiopia, in August 2014. This workshop included both scientists and the stakeholders involved with the project. The workshop was designed to present the scope of the project, engage the stakeholders/decision makers in the assessment of information requirements, and use feedback to reorient prediction models to address user needs. Several stakeholder engagement strategies were utilized during the workshop to increase scientist-stakeholder interactions and increase both the amount and usefulness of stakeholder feedback. For example, participants were given opportunities for discussing ways in which information could be delivered for easy use and to identify stakeholders that would use and evaluate the climate prediction tools. The CCF and its seven capitals described above were used as a guide for the stakeholder interactions and responses. Pre- and post-participation surveys were given to all participants to measure knowledge, attitudes, and the use of drought/flood prediction and climate-related information. Participants were also asked in the survey about local perceptions of current climate change impacts in the GHA.

Virtually all of the 30 survey respondents (93 %) perceived that climate change was affecting their country. Respondents were asked whether they had seen or heard about impacts (positive or negative) to a predefined list of 63 different resources, assets, and activities, due to climate change and extremes. Responses were mapped to the CCF capitals. Workshop participants identified impacts across all seven capitals. The greatest number of perceived impacts was to natural, built, and financial capitals and the lowest to human and cultural capitals (Table 2). Although the impact list was not comprehensive, these results suggest that the GHA is already having consequences in all of the community assets needed to foster economic development and sustainability and to build adaptive capacity for current and future climate change. Public health is going to be a very important factor given these issues. In comments written during the survey, and from verbal statements made throughout the workshop, participants supported these findings by stating that limited measures are in place for adaptation and mitigation and that a need exists for developing risk-based planning approaches and establishing a platform to build capacity, especially for ongoing socio-economic development that includes health.

During two breakout groups, "Agricultural and Water Impacts" and "Data Gathering-Sharing", participants were asked to consider climate hazard consequences, information sharing, specific information needs, and relevance of climate information in different sectors. Participants said they used weather and

Table 2. Workshop participant survey results

Type of capital	Number of perceived impacts			Top 3 perceived impacts from those listed in the survey
	Yes	No	I don't know	
Natural	218	8	35	Biodiversity, water quantity, insect manifestations
Built	211	9	34	Water wells, energy projects, dams, water and climate monitoring equipment (tie for 3rd)
Financial	205	6	50	Agricultural productivity, number of people in poverty, food costs
Political	176	6	74	Political or water-use conflicts, climate adaptation (tie for 1st), water-related policy, satisfaction with governmental leadership
Social	170	8	55	Population migration, social networks and organizations, public awareness of climate/water issues (tie for 2nd), public services
Human	156	5	71	Health/disease, quality of life, education and skills, size of labor force, access to medical treatment (3-way tie for 3rd)
Cultural	136	16	80	Sustainability practices, local foods and cuisines, and gender and age-based roles

climate information for decisions such as relief and humanitarian aid after disaster occurrence, estimating or forecasting agricultural production, and reservoir operations and flood management (e.g., drainages). They said they currently use globally available online climate information such as daily, decadal, monthly, seasonal, and annual prediction related to general early warning systems, as well as pre-during-post disaster information.

Interactions with workshop participants have been used to determine next steps for the project. The next workshop will take place in July 2015 and will involve coordinating with local hosts and translators to conduct interviews with potential users of the information. As throughout the project, the goal of the second workshop is to again utilize interactive participatory techniques to get to more specific uses and delivery of the information. Connections with the public health sector, and its use of these products and associated information for disaster and hazard preparedness, will be an important component of the workshop.

8 Case Study: Community Capitals Framework and Drought Impact Assessment

Systematic collection and archival of drought-related information on impacts has proved to be very difficult, in part because of the unique characteristics of drought described above. Although many efforts are underway to collect such

information [e.g., the NDMC's Drought Impact Reporter, the state of Arizona's initiative for collection called "Drought Watch", and the citizen science precipitation network called the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network], certain types of impacts [e.g., social, cultural, and human (which includes health)] are harder to capture and consequently less understood, and they are often not a robust part of planning and response (Downing and Bakker 2000; Lackstrom et al. 2013).

Given these challenges, the NDMC is leading an effort using CCF and its seven capitals to assess existing drought impact reports and develop a strategy to increase the breadth of future reporting. Because the CCF is designed to help communities assess their overall sustainability, it is a natural process to also assess the resilience to drought, potentially improving drought planning and mitigation efforts. Classifying drought impacts according to the CCF capitals is an opportunity to examine how changes in one type of capital may influence other capitals. For example, a decline in natural capital, such as water supply, can lead to declines in other capitals, such as financial capital (decreased farm income) or human capital (stress and depression, which are tied to health). Further, the use of this framework can allow for the identification of specific examples of under-reported impacts, which can then be used to develop approaches to effectively record and quantify a larger range of drought impacts.

An example application using CCF was examined for the 2012 drought across the central U.S. Drought-related impacts were studied using the Drought Impact Reporter (DIR) between May 1, 2012, and August 31, 2012, for five states (North Dakota, South Dakota, Nebraska, Kansas, and Texas). The total number of impacts reported during that time across the region was 1687, spread among the various DIR sectors (agriculture; business and industry; energy; fire; general awareness; plants and wildlife; relief, response, and restrictions; society and public health; tourism and recreation; and water supply and quality). The highest reported number of impacts came from agriculture (as would be expected because of the financial losses from drought). In the social and public health category, 220 impacts were recorded, but one could argue that most of the DIR categories are tied to health in one way or another. The second highest number of impacts was reported for the water supply and quality category, which is often tied to public health impacts.

Some of the possible direct and indirect health-related impacts reported for each of the capitals include:

- Human capital: increased respiratory illness, increased heat-related ambulance calls, increased (brown recluse) spider bites, farmers less optimistic about their future, and increased anxieties in the ethanol business;
- Social capital: voluntary and mandatory water reductions (primary health impact due to stress levels and future worry about water supplies), increased demands on volunteer fire and rescue (primary health impact due to stress levels and future worry about water supplies), and working overtime on repairing water mains;

- Cultural capital: cancelled 4th of July celebrations, closed swimming pools, and decreased hunting opportunities (primary impact especially to humans using hunting as part of their food supplies);
- Natural capital: Decline in rangeland grass production (secondary health impact due to financial stress or anxiety, perhaps later tertiary—due to food security and caloric reductions), trees susceptible to pests/disease, algae blooms in ponds (primary consequence to the species in the ponds and also humans using fishing as part of their food supplies), blowing dirt and grass fires (primary impacts to respiratory disease states), and wildlife deaths (primary impact to the species and also humans using hunting as part of their food supplies);
- Financial capital: Decreased crop yields (tertiary health consequence: food security and caloric reductions), increased water and energy rates (secondary health impact due to financial stress or anxiety), closed ethanol plants, and increased firefighting expenses;
- Built capital: Wells shut down, power outages, shifts and cracks in foundations, closed roads, homes destroyed in wildfires;
- Political capital: Activation of water restrictions, state of emergency declarations, improvements to USDA programs, opening of CRP lands for grazing, federal drought aid.

8.1 California

Four years into a serious drought, ABC News reported in April 2015 (Mohney 2015) that the ongoing drought could cause more problems for state residents by creating favorable conditions for infectious diseases such as the West Nile Virus and Valley Fever. The DIR captured several of these reports, including a report on a widespread Valley Fever outbreak in the San Joaquin Valley prison population and the need to find areas of relocation (National Drought Mitigation Center, Drought Impact Reporter 2013). In less than one year, reports indicated that at least 17 rural communities were at an acute risk of running out of water within 60 days and high numbers of rural communities were at especially great risk because of well contamination due to shrinking water supply levels (Zerkel 2014). This news of water shortages and contamination came right after President Obama's announcement that several million dollars would be directed toward aid for the State of California, including at least $60 million for food banks (The White House, Office of the Press Secretary 2014). As the drought continues, many public health officials are bracing for how to handle an increase in anticipated health impacts.

A widespread drought impact analysis for the state would help officials plan for resource allocations and resiliency, especially for rural communities without direct large investments into certain community capital areas (e.g., financial and built). Officials are also watching the link between drought areas and poverty, especially in terms of migrant workers, producers of livestock, and their

overall access to groundwater for food production and/or drinking (Community Water Center of California 2015).

Given this context, Watsonville, California, could be a good location to investigate these issues further. Much progress has been made in Watsonville over the years in strengthening their community capital areas. The community is situated in the fertile Pajaro Valley along Monterey Bay. It is surrounded by agricultural land that produces a large variety of fruits and vegetables for the U.S. It also has a very diverse immigrant population, with Hispanic being the most dominant. In 1989, the small community suffered extensive damage from an earthquake, which prompted city officials and citizens to come together to repair the community on all levels and continue to develop more extensive all-hazard plans. Also, giving immigrant populations local voting rights led to empowerment and an investment in the community's future. They have expanded their local economy to embrace business and industry, including one of the largest frozen vegetable companies. Watsonville officials also started to engage their youth and provide them more jobs in the community, which helped bring down a concerning rise in local crime rates (Luther and Wall 2008). With this history of addressing their current and future vulnerabilities, they have been able to solidify plans for their community out to 2030. Watsonville also produced a draft climate change action plan for their community in 2014. It is unknown if drought is specifically mentioned in either of these plans, but the constant stakeholder engagement process and the community's investment in various CCF capital areas has certainly set the stage for increased drought resilience in the community and the potential for reduced impacts, including those public health impacts being observed in other parts of the state.

9 Case Study: Missouri River Basin

The National Integrated Drought Information System (NIDIS) is a U.S. interagency approach created in 2006 to "enable the nation to move from a reactive to a more proactive approach to managing drought risks and impacts" (National Integrated Drought Information Center 2006). It is authorized to coordinate federal drought risk management efforts and to provide drought early warning integrating information and indicators of drought and drought severity. In order to accomplish this, NIDIS is developing a network of regional drought early warning systems (RDEWS), which build on existing monitoring and drought risk management activities. One of those RDEWS has been established to cover the Missouri River Basin (MRB) region in the central U.S.

The kick-off workshop event for the MRB RDEWS took place in Nebraska in February 2014. More than 70 federal, national, tribal, state, and local representatives who work in the area of drought monitoring and management within the MRB attended the workshop. Participants gave updates on the latest drought monitoring, prediction, and planning tools or methods that are applicable to a variety of stakeholder needs. The workshop also included multiple discussions related to data needs and resources to address various impacts

and vulnerabilities, including those related to water scarcity, water quality, and public health.

Because there was enough interest from participants to have capacity to cover the public health sector, the sector was featured in a "World Café" participatory breakout session facilitated by the NDMC, University of Nebraska Medical Center, and Nebraska Public Policy Center. The pre-derived questions for the session were gathered from various literature reviews, gaps in the available information related to drought and public health, and numerous discussions with the facilitation leaders. Lastly, based on goals to create an MRB RDEWS, some questions were created to address those future efforts: (1) what health impacts or concerns exist in your communities as a result of droughts? (2) What are the current perceptions related to drought and health impacts? (3) What health-related data or sources of information exist? (4) What programs, trainings, or partnerships exist to address climate-related health issues?

The health session received well-balanced input from various agency stakeholders, such as those who are involved in water quality/quantity and health concerns at federal, state, tribal, and local levels. This session included in-depth discussions on various drought-related health impacts in communities and possible sources of data to use in tracking these impacts more carefully. Impacts such as respiratory illness (asthma specifically) caused by higher temperatures and drier conditions are a huge concern in the Missouri River Basin. Increases in pollen rates and dust or particulates are already an issue for those living in rural areas. Pest and micro-organism increases have been connected to drought. Local water supplies are clearly connected to public health, underscoring the need for tracking water quality impacts more closely. Excessive heat can increase emergency room visits and death rates, especially in groups more vulnerable to the heat such as children, the elderly, people living without air conditioning, and people employed in occupations such as seasonal outdoor labor. Wildfires bring about more smoke-related respiratory illness, and it was noted that hospital evacuations took place in the basin because of neighboring wildfires.

The list of impacts provided an essential awareness of some public health problems caused by drought in the region. Participants still were unclear whether decision-makers in medical facilities within the region were planning for these types of high-impact events that can be either short or long term in nature. In addition, not all groups were represented at the session. For example, missing from the workshop were medical (such as epidemiologists and mental health) professionals, K-12 educators, and health and human services (federal and state level) professionals. However, it was a beginning—and a "kick-off" event. The goal was established that future MRB RDEWS planning activities should encompass discussions with these additional types of stakeholders. Additional discussions that should be high on a priority list include the known increases in mental health crises due to drought, especially when there are significant crop losses and drops in the rural local economy.

9.1 MRB RDEWS Tribal Activities

One of the goals of the MRB RDEWS is to engage tribes across the region and assist with improved drought risk management. The MRB RDEWS is currently working on various activities with tribes in Wyoming, South Dakota, Nebraska, and Kansas. Each of these activities has the potential to involve public health-related impacts, and the intent is to employ appropriate stakeholder engagement strategies to meet the unique needs of the tribes involved.

In part as an outcome of the kick-off workshop and its various discussions in February 2014, interactions have begun with the Wind River Tribes of Wyoming to address aspects of drought risk management, including improved drought monitoring and early warning and drought planning. These interactions have included a variety of engagement strategies including meetings, webinars, and in-person trainings to address climate and drought information needs, planning, and vulnerabilities. The North Central Climate Science Center and the NDMC, along with several other organizations and the Wind River Tribes and their Tribal Water Engineer's Office and Water Board, are partnering on a project that will look closely at the various vulnerabilities (including health) that the tribes face during periods of drought. This will also inform what kinds of drought planning needs and resources are required to address future water and overall health concerns for both tribes.

10 Conclusions

Several high profile natural disaster events over the past quarter century have highlighted how disasters and humanitarian crises can be linked (Leaning and Guha-Sapir 2013). More recently, there is a growing recognition that the public health impacts of all natural hazards, including droughts, and in all regions, need to be addressed in order to identify a location's vulnerability to these impacts and help that location or region become more resilient to future disasters.

To promote this holistic, proactive approach to building resilient societies, it is becoming common to hear and see people and organizations talk about "One" common theme, as in "One World", "One Water", and "One Climate" to link complementary efforts (CAFOD 2015; Knight Center for International Media 2015; OneWorld 2015). Recently, a "One Health" effort has evolved that embraces the close linkages between human, animal, and ecosystem health (CDC 2015). Highlighting these holistic and synergistic interdisciplinary and cross-sectoral approaches is necessary in order to tackle the complex issues related to the nexus of food, water, climate, energy, health, and societies. As one of the complex issues that will likely be exacerbated by climate change, this chapter on drought illustrates how improved early warning and stakeholder engagement,

such as the Community Capitals Framework, creates opportunity for iterative dialogues within and between sectors, and between scientists and stakeholders. These opportunities to inform better decision-making will, one hopes, translate into reduced public health impacts resulting from future drought events.

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