Lessons from California's 2012–2016 Drought

Jay Lund, Dist.M.ASCE[1]; Josue Medellin-Azuara, M.ASCE[2]; John Durand[3]; and Kathleen Stone[4]

Abstract: California's 5-year drought has ended, even as its aftermath lingers. From 2012–2016 much or all of California was under severe drought conditions, with greatly diminished precipitation, snowpack, and streamflow and higher temperatures. Water shortages to forests, aquatic ecosystems, hydroelectric power plants, rural drinking water supplies, agriculture, and cities caused billions of dollars in economic losses, killed millions of forest trees, brought several fish species closer to extinction, and caused inconvenience and some expense to millions of households and businesses. The drought also brought innovations and improvements in water management, some of which will better prepare California for future droughts. This paper summarizes the magnitude and impacts of the 2012–2016 California drought. The paper then reviews innovations arising from the drought in the larger historical context of water management in California. Lessons for California and for modern drought management are then discussed. Droughts in modern, well-managed water systems serving globalized economies need not be economically catastrophic, but will always have impacts and challenges, particularly for native ecosystems. In California and every other water system, droughts usefully expose weaknesses and inadequate preparation in water management. In this regard for California, managers of ecosystems and small rural water supplies had the most to learn. **DOI: 10.1061/(ASCE)WR.1943-5452.0000984.**

Introduction

Drought is a temporary reduction in water availability below normal quantities. Droughts can be for only a few weeks or endure for years or centuries—in which they blend with changes in climate. In rain-fed agricultural systems, droughts of a few weeks can be devastating. Places such as California, with a long summer dry season and a Mediterranean climate, each year face what would be the worst drought ever seen in more humid American states.

From 2012 to 2016, California experienced one of its deepest, longest, and warmest historical droughts. Many effects from this drought to forests, native fish populations, groundwater levels, and land subsidence will endure for decades. Lessons and innovations from the drought also will last for decades and improve California's ability to manage future droughts. Past and future droughts are always present in managing water in California. California enters each drought with management institutions, policies, infrastructure, water storage conditions, and water demands influenced by past droughts. Future droughts are also in the minds of water managers as they make agreements, contracts, storage, infrastructure, and marketing decisions to dampen potential drought impacts.

Drought has always been a risk to humans and natural organisms. Historically, drought has shaped and destroyed civilizations and ecosystems. Droughts and sometimes-accompanying climate change have been implicated in the decline and fall of civilizations (Shimada et al. 1991; Douglas et al. 2015; Krieger 2014; Staubwasser et al. 2003; Drysdale et al. 2005; Fagan 2009; Weiss 1997). For ecosystems, droughts can be pivotal events when invasive species become established or shifts occur in species composition (Winder et al. 2011). Yet, western US water management systems have become much more robust and adaptive than is commonly thought (Fleck 2016).

The onset of drought is slow. The water stored in soils, slowly diminishing springs, reservoirs, and aquifers dampens the onset of drought. The duration of droughts in California can be long and uncertain, perhaps lasting years, decades, and even centuries, compared with hours to days for fires and floods or minutes for earthquakes (Stine 1994). Therefore, signaling the onset and end of drought can be messy. Drought onset is usually slow, varying in local intensity, with an uncertain and often varying duration. Like all forms of disaster, preparation greatly diminishes drought losses, and organization is central to effective preparation and response.

For humans, the impacts of drought vary with economic, infrastructure, and institutional conditions, as well as the drought's hydrologic characteristics. The economic effects of drought depend on the economy's reliance on water and the extent of regional and global trade. Global economic connections greatly reduce the impacts of drought (Sumner 2015; Lund 2016a). Global food trade largely eliminates the existential threats of drought to civilizations, and greatly eases drought's economic and public health impacts. Infrastructure networks and institutions that store, move, and reallocate water flexibly also greatly reduce drought impacts (Lund 2016a). Regional hydrologic characteristics, such as large freshwater aquifers, can dampen drought effects.

However, actions taken to minimize the impact of drought for humans often further jeopardize vulnerable ecosystems and other environmental resources. California has arguably restructured its infrastructure and economy to accommodate droughts, but many of these actions have further altered habitats and streams in ways that harm native species, which once were well adapted to California's droughts using once-vast habitats connected to snowmelt, springs, groundwater, and seasonal floodplains. Losses to native species populations during drought are often not recovered before the next drought.

[1]Professor, Dept. of Civil and Environmental Engineering, Univ. of California, Davis, CA 95616 (corresponding author). Email: jrlund@ucdavis.edu

[2]Acting Associate Professor, Environmental Systems Engineering, Univ. of California, Merced, CA 95343. Email: jmedellin-azuara@ucmerced.edu

[3]Assistant Research Scientist, Center for Watershed Sciences, Univ. of California, Davis, CA 95616. Email: jrdurand@ucdavis.edu

[4]Graduate Student, Dept. of Civil and Environmental Engineering, Univ. of California, Davis, CA 95616. Email: katstone@ucdavis.edu

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