

THINKING ABOUT RISK ON THE COLORADO RIVER

(May, 2019)

In workshops in 2017 and 2018, approximately 100 of the leading water-supply and river managers, scientists, and stakeholders concerned about the future of the Colorado River assembled to identify key research needs in the basin. One of the most prominent themes that emerged from those discussions was the need to better understand how the river system is vulnerable to low-probability, high-impact events that fall outside the scope of normal expectations and existing management plans. Included in this category are completely unexpected shocks, so-called “black swan” events, as well as the more familiar and predictable, albeit highly improbable, events. Many of these risks pertain to extreme hydrologic conditions, including megadroughts and catastrophic floods. Other risks include possible physical phenomena that might further undercut ecosystem stability affecting endangered species and environmental restoration efforts, and socioeconomic events that might stress the existing legal/management framework beyond any known circumstance. There are many reasons to believe that the likelihood of such events occurring in the Colorado River basin is increasing at the same time our water-supply safety net—including reservoir storage, ground-water reserves, and “unused” apportionments—is increasingly under unprecedented stress.

As the states of the Colorado River basin reconvene in 2020 to negotiate new rules concerning how to allocate the pain of water-supply shortage and thereby supplant the expiring Interim Shortage Guidelines and Minute 323 of the Mexican-US Water Treaty, an opportunity and need exists to do so with an eye toward the full range of potential futures that may stress the region and the river. Many of the current management challenges in the basin—including the thorny problem of overallocation—can be traced back to poor planning assumptions regarding hydrology, climate, and consideration of the full spectrum of the river’s values and services. To do better in the future will require good data fed through well-constructed scenarios and planning frameworks. Central to this effort will be scientifically informed anticipation about the low-probability, high-impact events that have thus far received little attention outside of small subsets of the scientific community. To that end, we encourage planning processes embracing a wide range of possible climate futures and societal responses to those future conditions.

The Hydrologic Swans

The Colorado River basin has warmed steadily in recent decades and will continue to do so as long as humans emit greenhouse gases into the atmosphere. This warming, which is already causing river flows to decrease, is a component of a wider range of interrelated climate change impacts to watershed runoff, stream flow, and water demands. More frequent and intense extreme events are expected in a warmer future. To the extent that the rarest of these events (i.e., the extreme tails of the probability curves) fall outside of what is considered reasonably possible, the occurrence of these events has the potential to blindside and overwhelm management systems.

Perhaps the most acknowledged of these risks is megadrought—a drought measured in multiple decades rather than years. When compared to the paleohydrologic record, the first 19 years of the 21st century are already among the five driest extended periods in the past 1,200 years. Whether the current period is characterized as the beginning of a new megadrought, or whether the low basin runoff of the early 21st century is merely a consequence of an emerging aridification trend (discussed in an earlier CRRG publication¹) associated with rising temperatures—or a combination of both—is unknown. Whatever the case, the present is a condition that is quite anomalous with respect to the 1906-to-present historic record used in most water scenario planning. This situation is disconcerting given the role of multiple megadroughts in undermining past civilizations in the region, namely the Ancestral Puebloans (Anasazi) on the Colorado Plateau (mid-1100s and late 1200's) and the Hohokam in Arizona (late 1200s and late 1400's). This kind of a possible black swan hydrologic event—a protracted megadrought—demonstrates that planning scenarios should consider a longer hydrologic record than the last century. In fact, the abnormally wet period of the early 20th century that water managers have traditionally considered part of the “normal” watershed runoff pattern might be better viewed as a highly unlikely hydrologic event that cannot be assumed to be part of the future.

There are multiple pathways for a megadrought to overtake the Colorado River Basin in the coming decades of the 21st century. First, there is the likelihood that the current drought, driven by warming as much (or more) than precipitation deficit, might continue to worsen for years or decades into the future. The risk of such aridification certainly increases with time unless greenhouse gas emissions are curbed, and could yield a more or less permanent (on human time scales) megadrought worse than any of the last

Suggested Scientific Literature on Hydrologic Risks

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O'Connor, J.E., L.L. Ely, E. Wohl, L.E. Stevens, T.S. Melis, V.S. Kale, and V.R. Baker. (1994). A 4500-year record of large floods on the Colorado River in the Grand Canyon. *Arizona Journal of Geology*, 102, 1-9.

Routson, C.C., C.A. Woodhouse, and J.T. Overpeck (2011). Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought? *Geophysical Research Letters*, 38, L22703, doi:10.1029/2011GL050015.

USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp., doi: 10.7930/J0J964J6.

Woodhouse, C.A., and J.T. Overpeck (1998). 2000 years of drought variability in the central United States. *Bulletin of the American Meteorological Society*, 79(12), 2693-2714.

¹ *When is Drought, Not a Drought? Drought, Aridification, and the “New Normal”* (March, 2018), <https://www.coloradoriverresearchgroup.org/publications.html>

1,000 years. This scenario is in line with recent assessments of future Colorado River stream-flow reductions driven by continued warming. Additionally, there is still the risk that natural variability could trigger megadroughts in the future, and that these megadroughts could be as long and severe as those in the recent geologic past. Megadroughts lasting as long as 50 years have occurred in the shared headwaters of the Colorado River and Rio Grande. The odds of such extreme drought happening again only go up as the planet warms.

Perhaps less appreciated are the risks of catastrophic flooding in the basin. The spillways at Glen Canyon Dam were significantly eroded by cavitation in 1983, as were those at Oroville Dam (in California) in 2017, when floodwaters exposed weaknesses of existing infrastructure. Although weather prediction and water resource management plans have improved and been revised following the events at Glen Canyon Dam, there is nevertheless the possibility that an unusually large flood might occur in the basin headwaters. We know such great floods have occurred in the past (outside of the relatively short stream gauge period) based on field observations of the flood deposits and analysis of the paleohydrologic record. Even if Lake Powell and Lake Mead remain low, megaflood risk persists and is likely to be increasing. Precipitation intensity, and the amount of precipitation falling in the most intense events, are increasing globally and across the United States, in large part because sea surface temperatures and atmospheric water vapor content are both rising, increasing the odds of more extreme precipitation events. These trends will continue as long as emissions of greenhouse gases to the atmosphere continue.

Recent scientific work also highlights that the climate system may have more multi-decadal variability than previously thought, or than simulated by state-of-the-art climate models. This variability has most famously manifested itself in the form of past megadroughts, but may also generate periods of above normal precipitation, or “mega-pluvials.” It is conceivable that such a wet period could reoccur in the future, only to be supercharged by warmer sea surface temperatures and atmospheric moisture content to yield a combination of much above normal late-season snowpack (remember 2015’s “Miracle May”), more intense melt-season runoff, and an extreme and persistent rain event in just the right location to generate an unprecedented megaflood. Short lead times, when combined with a dependence on often untested (and perhaps under-capacity) flood control infrastructure, often leave managers with few tools to deal with such extremes.

Other Risks

Adapting planning frameworks to consider threats beyond the hydrologic black swans creates even more challenges. Recent history in the basin has featured dozens of salient stressors that, while not completely unanticipated, were outside of the scope of past planning endeavors. Examples include the massive loss of forest ecosystems in the Rocky Mountains and Pacific Northwest from beetle kill, the destruction of Mexican water delivery infrastructure in the 2010 earthquake, and the introduction of new exotic species (e.g., quagga mussels). Other conceivable risks include shocks to world trade that shift energy costs or agricultural production, the potentially unpredictable impact of national immigration policy on other aspects of relations with Mexico, and regional economic booms and recessions. As the recent DCP negotiation highlighted, two of the most problematic features of the current management framework—the inability of Pinal County, Arizona farmers to easily absorb CAP curtailments, and the environmental and public health challenges associated with limiting Salton Sea inflows—have influenced, and are influenced by, matters that were heretofore considered outside of basin water management planning.

Certainly it is not realistic to charge water managers with simultaneously addressing all possible interrelationships among water-related sectors, especially in the context of totally unexpected black swan events. But it is reasonable to expect planning and decision-making efforts, such as the basin states negotiations over new guidelines, to broaden the scope of scenario planning as applied to the analysis of water delivery reliability. At a minimum, environmental needs should be an integral part of that assessment. Similarly, it is increasingly evident that the decision-making mechanisms through which new challenges are addressed must become more agile. Admittedly, identifying planning processes that are both broader in scope yet support more agile and adaptive management in application is a heavy lift, but it is a challenge the Basin's water management and policy community must accept.

Conclusion

Omitting low-probability, high-impact events from future scenario planning efforts on the grounds that we are powerless to prepare for what we cannot fully anticipate or comprehend is both foolish and unnecessary. The reality is that we are learning a great deal about many such risks. For example, one step forward is Reclamation's recent emphasis on "stress test" modeling, which assesses how the water delivery system would perform if the hydrology of recent decades were to persist. Perhaps the next step could take inspiration from the approach used in the Severe Sustained Drought study of the early 1990s, which used the hydrology of a megadrought from the late 1500s to test modern system performance under extreme water scarcity, focusing not only on water deliveries, but on the drought's economic and environmental impacts, legal/political ramifications, as well as considering potential coping mechanisms. And even if we cannot predict what the next actual black swan event will be, basin managers can establish a *process* to continuously evaluate all of the climatic, hydrologic, socio-political, economic, and other trends that might affect basin management, and to advise on the implications of those factors and possible ways to mitigate or address them. Many researchers in the academic community are already mobilized to assist in this effort.

Undoubtedly, the basin will continue to experience events and conditions that surprise even the most insightful managers and diligent researchers. Effectively dealing with these risks will test the social capital built up among basin leaders and the limits of our governance regimes. The (generally) collaborative environment among water managers that has evolved over the past 15 years is a welcome asset in this increasingly turbulent period. The renegotiations of the Interim Guidelines is a looming (although not isolated) opportunity to build upon that framework, and to create increasingly broad and inclusive planning frameworks to seek truly robust management solutions.

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