The Usefulness of Streamflow Reconstructions: Understanding the Management Perspective

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Abstract

The usefulness of extended records of streamflow from tree-ring based hydrologic reconstructions seems obvious- a longer record provides a broader range of the variability of extremes and allows recent and/or ongoing events to be evaluated in a long-term context. The information from these centuries-long records may have clear implications for water resource management, but it is often unclear exactly how this information can be applied to management. In this presentation, I will discuss some of the challenges I have observed that are involved in using streamflow reconstructions in management decisions. These range from issues related to an agency's capacity to use new types of data to mismatches between what is needed (e.g., daily resolution, a network of gage inputs) and what reconstruction data provide. The skillfulness of a streamflow reconstruction also has a bearing on its perceived credibility in terms of useable data. In spite of these challenges, there is a variety of ways that these data have been used by water resource managers in the western US. The uses are often not immediately evident, but can take the form of, for example, sensitively assessment, awareness raising, and shifts in prior assumptions. Relationship building between researchers and resource managers can yield mutual respect and understanding that lead to both interesting research questions and relevant and valuable information, even if the application to management is not tangible or immediate.

The Usefulness of Streamflow Reconstructions: Understanding the Management Perspective

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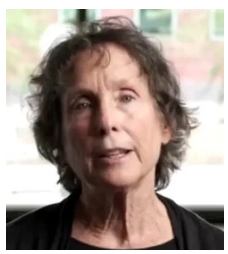


PRESENTED AT:

I. INTRODUCTION

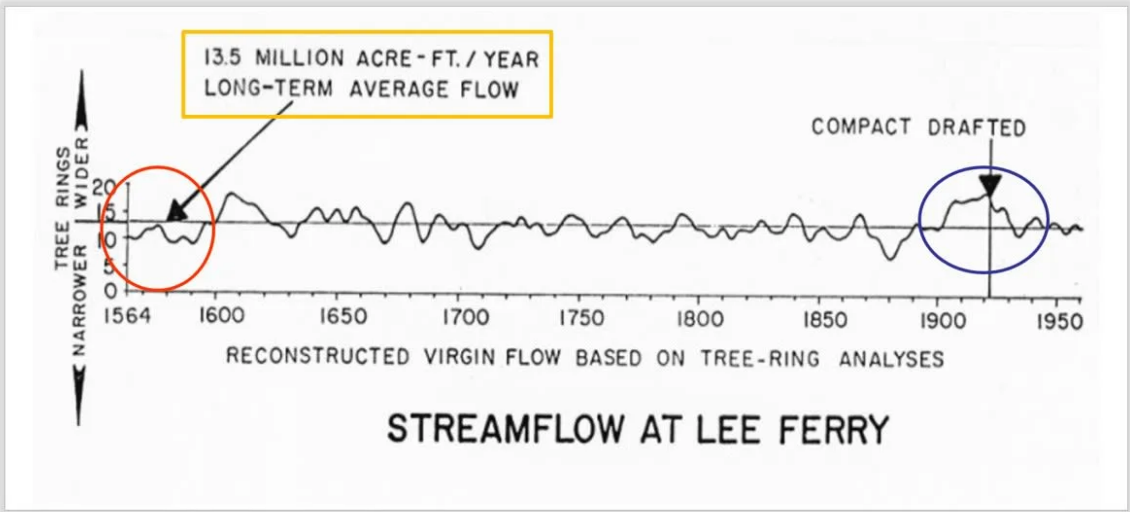
This goal of this presentation is to shed some light on how water managers might perceive the usefulness of tree-ring based hydrologic reconstructions in the hope that these insights may help others in their work with water resource managers. I am not a water resource manager (or a hydrologist!), so these reflections are based on my experiences working with water managers and the insights I have gained on the management perspective from these experiences.

The usefulness of extended records of streamflow from tree-ring based hydrologic reconstructions seems obvious -- a longer record provides a broader range of the variability of extremes and allows recent and/or ongoing events to be evaluated in a long-term context.

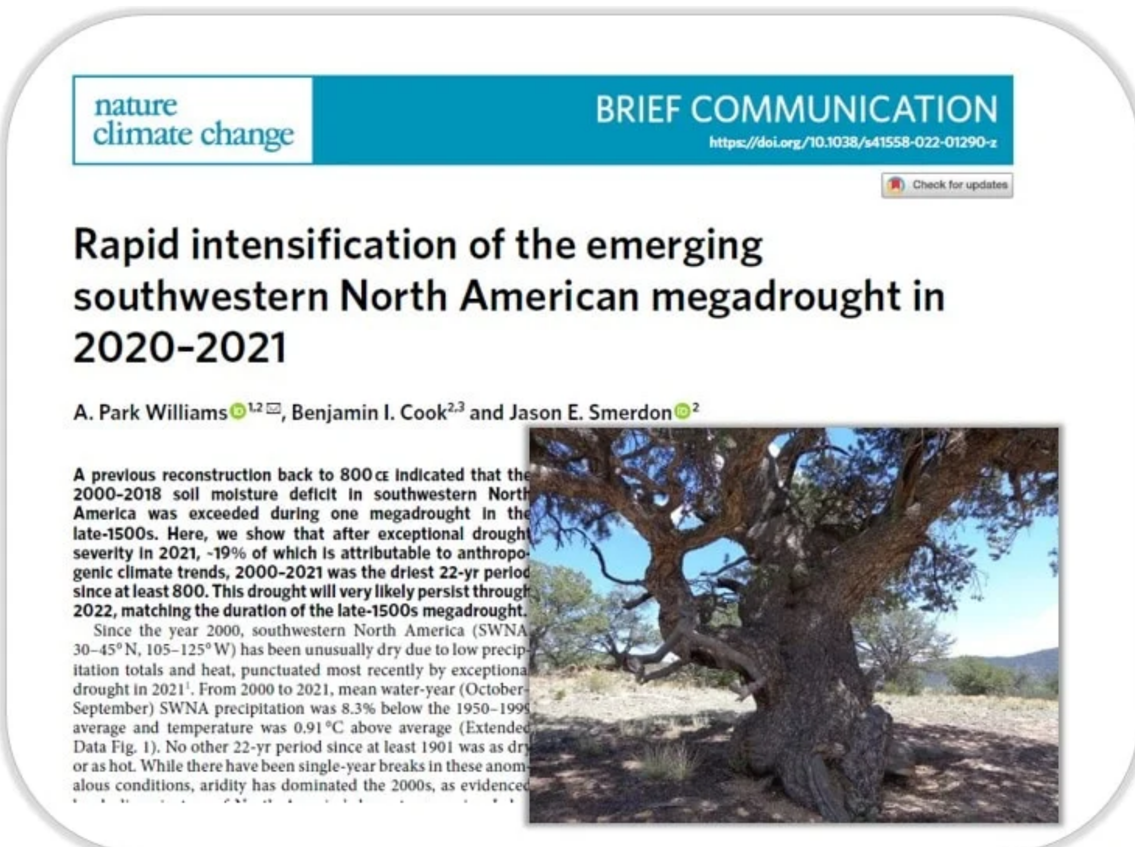
A very classic example of this is the allocation of Colorado River water in the 1920s. The Colorado River Commissioners (*photo below*), representing each of the seven basin states, negotiated the allocation based on an overly optimistic estimate of average annual flow (Kuhn and Fleck 2019). The resulting Colorado River Compact allocated 7.5 million acre feet (MAF) to the upper basin and the same to the lower basin, as measured at the Lees Ferry gage, with an additional 1.5 MAF allocated to Mexico in 1944, for a total of 16.5 MAF.


Colorado River Commission, 1922, from Water Resources Archive, CSU

In 1976, the first reconstructions of Colorado River flow provided a long-term context for this allocation. Stockton and Jacoby (1976) produced several different reconstruction models, but their “best” reconstruction (1520-1961 CE), had a long-term average of just 13.5 MAF (*figure below*). These findings had clear implications for the over-allocation of Colorado River resources.



Another more recent example is the reconstruction of drought based on a gridded network of soil moisture for the US Southwest from Williams et al. (2022) which found the recent 22-year period, 2000-2021, to be the driest period in the past 1200 years. Moreover, this dryness was strongly exacerbated due to anthropogenic warming. This result clearly has implications for water resource managers in this region. What is not clear is exactly how this information could be applied to management.


nature climate change

BRIEF COMMUNICATION

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Check for updates

Rapid intensification of the emerging southwestern North American megadrought in 2020–2021

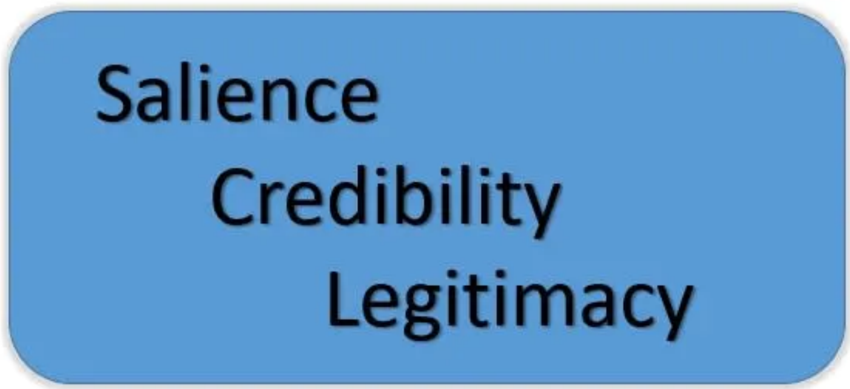
A. Park Williams[1,2], Benjamin I. Cook[2,3] and Jason E. Smerdon[2]

A previous reconstruction back to 800 CE indicated that the 2000–2018 soil moisture deficit in southwestern North America was exceeded during one megadrought in the late-1500s. Here, we show that after exceptional drought severity in 2021, ~19% of which is attributable to anthropogenic climate trends, 2000–2021 was the driest 22-yr period since at least 800. This drought will very likely persist through 2022, matching the duration of the late-1500s megadrought.

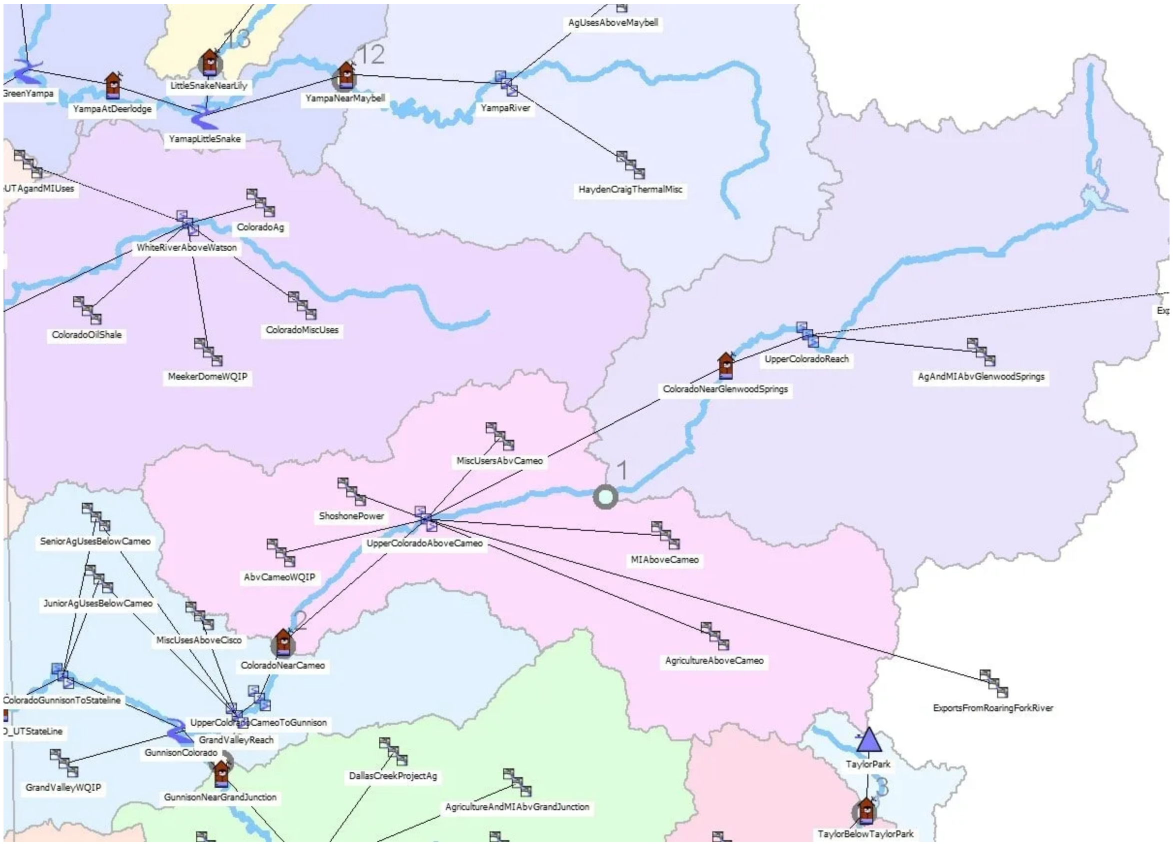
Since the year 2000, southwestern North America (SWNA, 30–45° N, 105–125° W) has been unusually dry due to low precipitation totals and heat, punctuated most recently by exceptional drought in 2021[1]. From 2000 to 2021, mean water-year (October–September) SWNA precipitation was 8.3% below the 1950–1999 average and temperature was 0.91 °C above average (Extended Data Fig. 1). No other 22-yr period since at least 1901 was as dry or as hot. While there have been single-year breaks in these anomalous conditions, aridity has dominated the 2000s, as evidenced

II. CHALLENGES IN USING STREAMFLOW RECONSTRUCTIONS IN WATER RESOURCE MANAGEMENT

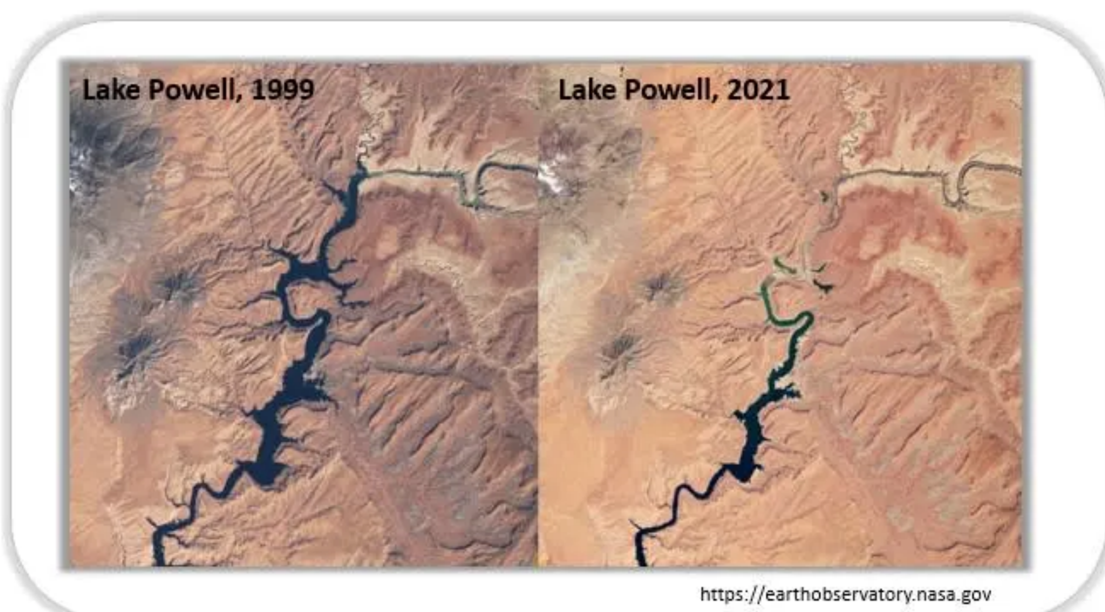
There are a number of challenges involved in using streamflow reconstructions in management decisions. In general, for scientific information to be applicable to decision making, it must be deemed to be salient, credible, and legitimate (Cash et al. 2002), and this is often not the case if researchers and managers have not collaborated on the development of the reconstructions. To be useful, a streamflow reconstruction must be for a gage of interest and the information it provides must be relevant to a current management concern. The credibility of the reconstruction, assessed in terms of accurate, valid, and high-quality information, is evaluated through the peer-review process, scientifically, but via other types of "peer" assessments as well. Credibility can also be related to the skill of the reconstruction. Finally, in order to be perceived as legitimate, the process by which the reconstruction was developed must be transparent and ideally involve input from the intended users.



In addition to these three factors, the capacity of the water management agency or organization can determine whether (and how) information and data from a streamflow reconstruction can be applied. In my experience, agencies that employ water supply system models may be better positioned to apply these data to management questions, but technical challenges can include the need for spatial and temporal disaggregation in order to match the inputs required by the management model (*example below, for the upper Colorado River*).



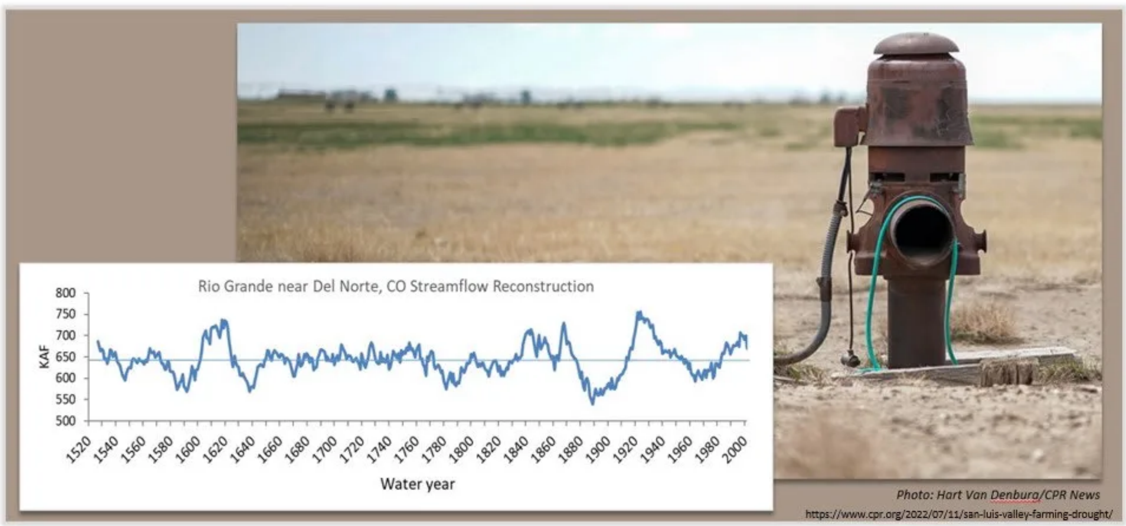
Uncertainty in the reconstruction may be difficult to incorporate into system models as well, so while the uncertainty information is important to convey, reconstruction ensembles may not be useable. Agencies that do not use water system models may find it more difficult to determine the value of a reconstruction, but it can be informative in a more qualitative way (Woodhouse and Lukas 2006). Related to capacity, timing can also be a critical factor. Water managers are often receptive to new types of information when events such as droughts present management challenges, but much less so when water supplies appear to be plentiful (e.g., Lake Mead in 1999 vs 2021, *below*).



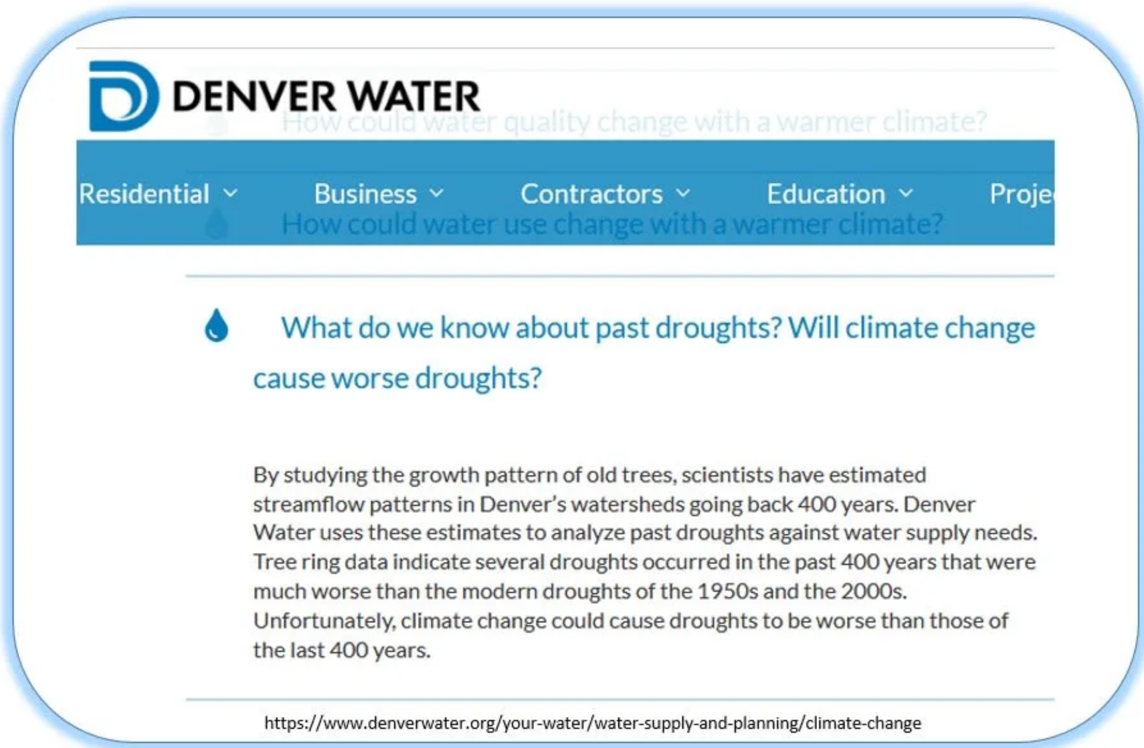
III. APPLICATIONS OF STREAMFLOW RECONSTRUCTIONS IN WATER RESOURCE MANAGEMENT AND PLANNING

When researchers engage with water resource managers, the potential for the application of streamflow reconstructions to decision making and planning is increased. Engagement can take a variety of forms, from the researcher serving as a consultant to a fully transdisciplinary process with resource managers as equal partners in a research project at every step of the way. While water providers or agencies with resources to support a scientific staff have the best capacity to make use of streamflow reconstructions, an increased awareness of equity issues may prompt researchers to use more inclusive approaches to collaboration with water stakeholders who have more limited capacity to explore new types of data.

There is a wide range of ways in which reconstructions of streamflow based on tree rings are being use in water resource management. I use my experiences with colleagues and a number of different water resource agencies in Colorado to provide some examples. At a fundamental level, centuries-long records of past streamflow provide an awareness of the nature and range of hydrologic variability, beyond that documented in gage records. In the Rio Grande headwaters region, the reconstruction of Rio Grande streamflow (*below*) offered water managers insights on the low frequency variability of the system, with implications for the current level of groundwater pumping in the basin.



This extended range of variability also documents extremes, including pluvial periods and multi-year droughts. Before the current drought, water managers in Colorado had commonly used the 1950s drought as a “worst-case” scenario. Reconstructions record how often 1950s-scale droughts occur, as well as droughts that were even more severe. Several water providers in the Colorado Front Range used this information to either confirm the robustness of their drought planning or to adopt new worst case scenarios (Denver Water is an example, *below*)


DENVER WATER

Residential | Business | Contractors | Education | Proje

How could water quality change with a warmer climate?

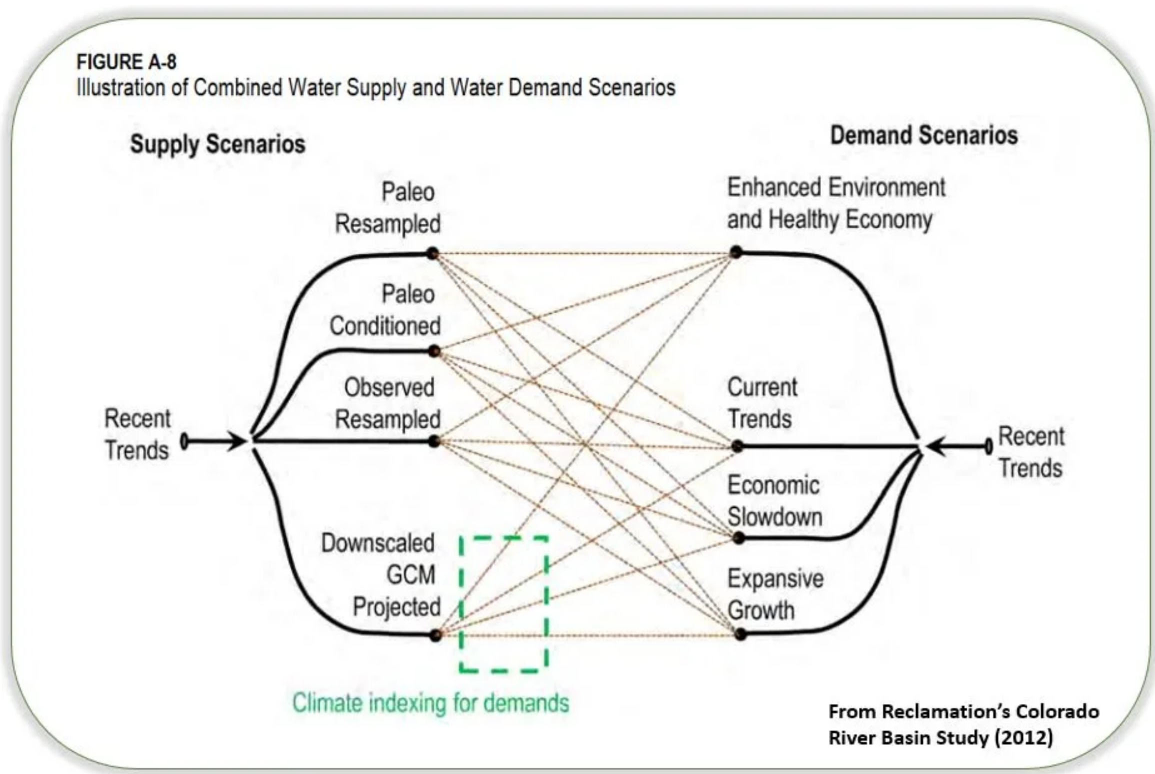
How could water use change with a warmer climate?

What do we know about past droughts? Will climate change cause worse droughts?

By studying the growth pattern of old trees, scientists have estimated streamflow patterns in Denver's watersheds going back 400 years. Denver Water uses these estimates to analyze past droughts against water supply needs. Tree ring data indicate several droughts occurred in the past 400 years that were much worse than the modern droughts of the 1950s and the 2000s. Unfortunately, climate change could cause droughts to be worse than those of the last 400 years.

https://www.denverwater.org/your-water/water-supply-and-planning/climate-change

Water providers and agencies who use water supply system models have used reconstructions of streamflow as input into models to see how the system performs under the worst droughts of the past and for sensitivity testing. An example of this is the Bureau of Reclamation's use of Colorado River reconstructions in their Colorado River Simulation System model, first to test system response, including changes in reservoir levels, to a multidecadal drought in the 1100s, and then in supply scenarios in their Basin Study (Woodhouse and Lukas 2020, Reclamation 2012) (*figure below*).



In addition, we have found that the reconstructions of past streamflow have been used by water managers to educate their customers and to communicate risk and support recommendations to decision makers (Rice et al. 2009). The table below includes this and other uses from a survey of 29 water managers in the Colorado Front Range.

TABLE 5. Survey Responses to the Question "How Have Tree-Ring Data Been Used by You, Your Organization, or Organizations That You Consult For?" (respondents could select more than one answer).

To broaden understanding of hydrologic variability	75%
To educate users/public	46%
To educate board and other decision makers	50%
As input into a water system model or other model	25%
For quantitative analysis, but not in a modeling environment	14%
To inform planning and decision making	54%
I have not used tree-rings in my organization	18%

From Rice et al. 2009

IV. CONCLUDING THOUGHTS

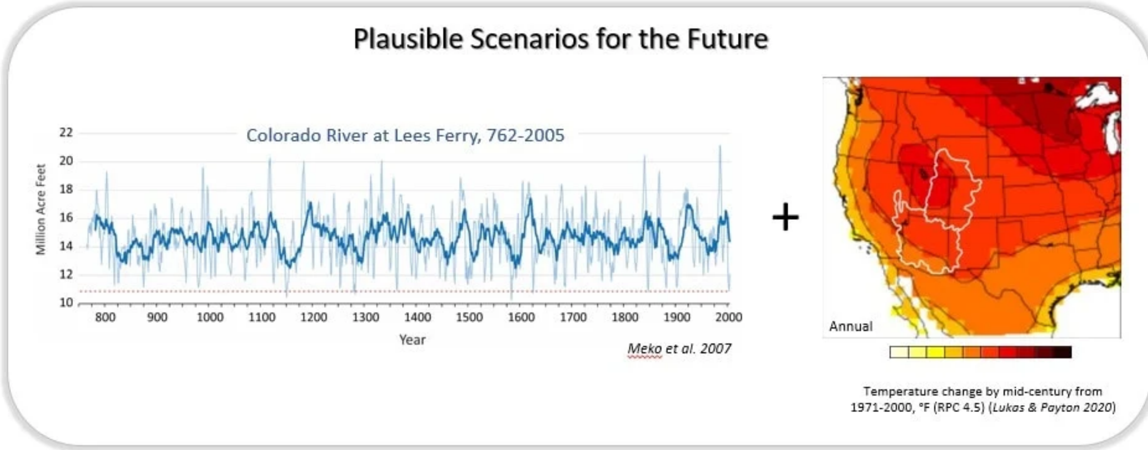
1. In my experience, there have been a very limited number of cases in which it is possible to point to a decision or a change in management that was made based on new information from a streamflow reconstruction.

2. Most often, water managers interested in a reconstruction do not have a concrete application in mind. The information from the reconstruction may be useful primarily for awareness-raising or education. If the information is used in some way, evidence of application may not be immediate or tangible. Actual use of this information may depend on a variety of factors, including timing, funding, leadership, and climate conditions and events.

3. The application of information from streamflow reconstructions is often in support of decisions that consider a host of other factors. It is important to recognize that scientific information is just one of a number of considerations in decision making. The decision-making context includes issues such as existing policies and planning practices, economic and financial constraints, risk/benefit trade-offs, politics, and overall feasibility of incorporating new data or information.

4. There is a growing track record of the use of streamflow reconstructions in water management in watersheds across the western US (and in other areas as well). These examples may help water managers in other watersheds consider how this information may be useful to them. My experience is that water managers greatly value learning from their peers and hearing about their experiences with tree-ring data.

5. Some have suggested that records from the past are no longer relevant given anthropogenic climate change. It is true that the past is not an analogue for the future. However, plausible future scenarios for water management include the range of conditions documented by paleohydrologic data with the added influence of warming *(illustrated below*). The blending of these two is being accomplished in a variety of ways, providing important insights for future planning.



Acknowledgements

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ABSTRACT

The usefulness of extended records of streamflow from tree-ring based hydrologic reconstructions seems obvious; a longer record provides a broader range of the variability of extremes and allows recent and/or ongoing events to be evaluated in a long-term context. The information from these centuries-long records may have clear implications for water resource management, but it is often unclear exactly how this information can be applied to management. In this presentation, I will discuss some of the challenges I have observed that are involved in using streamflow reconstructions in management decisions. These range from issues related to an agency's capacity to use new types of data to mismatches between what is needed (e.g., daily resolution, a network of gage inputs) and what reconstruction data provide. The skillfulness of a streamflow reconstruction also has a bearing on its perceived credibility in terms of useable data. In spite of these challenges, there is a variety of ways that these data have been used by water resource managers in the western US. The uses are often not immediately evident, but can take the form of, for example, sensitively assessment, awareness raising, and shifts in prior assumptions. Relationship building between researchers and resource managers can yield mutual respect and understanding that lead to both interesting research questions and relevant and valuable information, even if the application to management is not tangible or immediate.

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