

How Low a Colorado River Flow to Go?

Insights from numerically stabilizing Lake Powell and Lake Mead during crisis.

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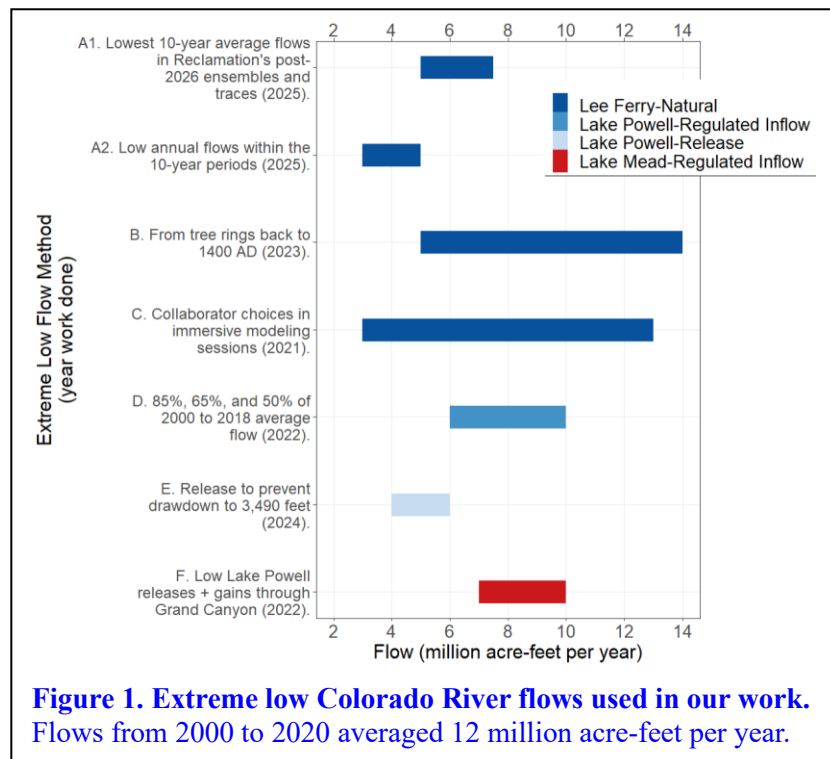
Introduction

Colorado River users are now discussing dividing river flow on a percentage basis ([Fleck, 2025](#); [Hager, 2025](#), [Winslow, 2025](#)). This is an important step to managing a declining and more volatile supply. In our prior May 2025 post, we shared a strategy we have worked on for several years—division of river flow—as one of [13 reasons why we have hope for consensus on Colorado River management](#). In this post, we address the question: *How extreme low river flow and reservoir storage should we plan for?* We also share 6 insights from strategies we used to numerically stabilize Lake Powell and Lake Mead during those crises and discussions of strategies with basin partners going back to spring of 2021.

Motivations to focus on extreme low flows and low storage

Traditional water planning exercises use hundreds to thousands of scenarios for future hydrology that are forecasted out decades ([Kasprzyk, 2013](#); [Porse, 2015](#); [Smith, 2022](#); [Salehabadi, 2024](#); [USBR, 2023](#)). These studies evaluated candidate operations by the number of scenarios that had catastrophic failure, such as reservoir drawdown to minimum power or dead pools. Modelers then sought to modify operations to reduce the risk of failure to some acceptable level. Our work is instead motivated to keep the Colorado River system *safe during crisis*:

1. By *crisis* we mean scenarios of extreme low flow and low storage—conditions we have yet to experience (Figure 1).
2. By *system* we mean protect infrastructure, generate hydropower, sustain native fish, and continue to deliver some water to agriculture, urban, and Tribal water users.



3. By *keep safe* we mean stabilize reservoir storage above protection elevations/volumes across *all* scenarios of extreme low flow and storage.

If we can stabilize and recover reservoir storage during crisis, then we can manage for less extreme conditions.

Scenarios of extreme low river flow and strategies to stabilize reservoirs

A. Sequences of extreme low natural flow at Lee Ferry ([Myers, 2025](#)). We filtered the super-set of 1,750 traces Reclamation is using in the Post 2026 planning process for the extreme low flows. We found 121 traces with at least one period of consecutive 10-year flow between 51 to 75 million acre-feet (maf). Within those sequences we further found 28 to hundreds of annual natural flow values in the range of 3 to 5 maf per year. More importantly, we found that low flows continued for more than

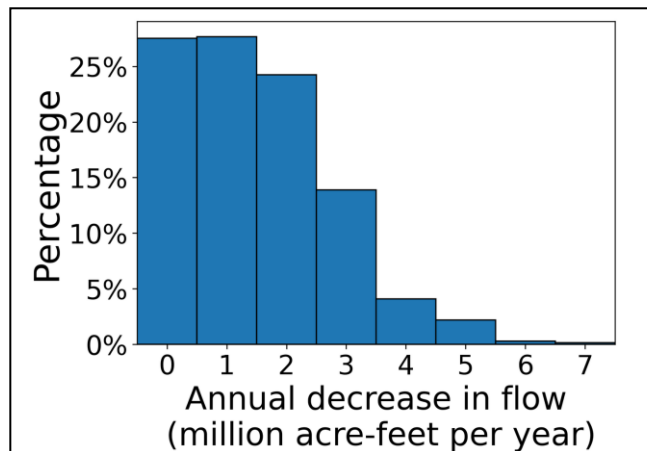


Figure 2. Occurrences of decreases in annual natural flow at Lee Ferry within 10-year sequences of low flows.

1 year or *decreased* by 2 or more maf from one year to the next year (Figure 2). Presently, we are holding immersive online collaborative modeling sessions to learn why partners can and cannot stabilize Lake Mead during these extreme low flows. In one strategy, collaborators set the reservoir protection elevation. Then, they sustain the elevation by taking a share of the Lake Mead inflow equal to their share of reservoir evaporation. Find more information on Github [here](#).

- B. Capped basin depletions to an amount equal to flow over a lookback period of 10 years** ([Wang, 2023](#)). We used worst case natural flow at Lee's Ferry down to 5 million acre-feet (maf) per year derived from tree rings dating back to 1400s AD. Capping depletions sustained Lake Powell and Lake Mead above their critical levels for long periods of time. This strategy of a lookback period was included in Reclamation's post-2026 web tool ([USBR, 2023](#)) and was part of the Cooperative Conservation alternative presently under study ([Pitt, 2024](#); [USBR, 2025](#)). A shorter look back period is also now in current discussions. The peer-reviewed paper is [here](#).
- C. Managing a combined Lake Powell-Lake Mead system based on reservoir inflow** ([Rosenberg, 2024](#)). During summer and fall of 2021, twenty-six Colorado River basin partners immersed in and personified one of 6 basin water user roles (Upper Basin, Lower Basin, Mexico, Tribal Nations, Colorado River Delta, and Shared reserve). Each collaborator joined 1 model session. Partners first articulated a water banking strategy for their user. Next, they choose the annual natural flow above Lake Powell. The model

divided the natural flow among the users and subtracted reservoir evaporation. Partners then entered the volume of water to consume, save, and trade in response to their account balance, others' choices, and the real-time discussion of choices. In the collaborative model environments, partners choose natural flows less than—and in several cases 67% of—recent average flow (Figure 3). Partners sustained reservoir storage because they could never withdraw more than their account balance. Basin partners are now discussing a challenging part of this approach: how to divide river flow among the users. The peer-reviewed paper is [here](#).

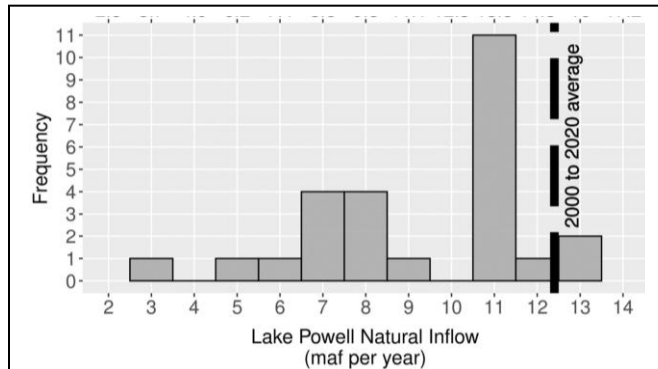


Figure 3. Collaborator choices for future natural flow above Lake Powell.

D. Release 95% of Lake Powell inflow ([Abualqumboz, 2022](#)).

This work used steady regulated Lake Powell inflows of 10, 8, and 6 maf per year each year that were 80%, 65%, and 50% of observed flows for the period 1988 to 2018. We programed a new, high priority rule for Lake Powell in the Colorado River Simulation System (CRSS) model. The rule released 95% of inflow in each time step, typically 3 to

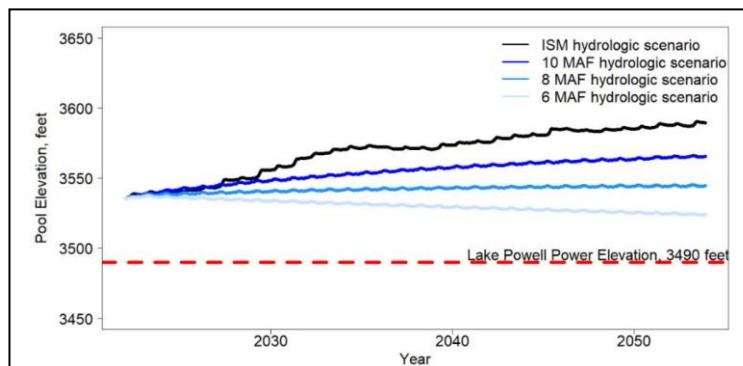


Figure 4. Lake Powell's pool elevation with Lake Powell outflow set to 95% of its inflow. ISM indicates historical inflow.

6.5 maf per year. The 5% reduction in release from inflow was typically greater than reservoir evaporation. Lake Powell levels stabilized and recovered in a few years across the range of assumptions for hydrology (Figure 4). This approach was similar to the “run-of-river” feature in Reclamation’s post 2026 web tool. Find the preprint on Utah State University’s Digital Commons [here](#).

- E. Further testing of rules to release less than inflow in Reclamation’s post-2026 web tool confirmed the **need for Lake Powell releases as low as 4 to 6 maf per year to protect Lake Powell from drawdown below minimum power pool**. Find more results on Github [here](#).**
- F. Defined a rule curve that specified the reservoir release to stabilize Lake Mead for regulated inflows of 7 to 10 maf per year that represented Lake Powell releases of 6.4 to 9 maf per year plus 0.6 to 1.0 maf per year of gains through Grand Canyon. Find the peer-reviewed (paywall) version [here](#) and free version on USU Digital Commons [here](#).**

Insights from stabilizing reservoir storage under extreme low flows

Technical:

1. ***Natural flow is easy to model numerically but difficult to implement in practice.*** The challenge is how to estimate flow during the time period the flow is occurring and before calculations to estimate natural flow are made from the upstream gaged flows, diversions, and consumptive uses.
2. ***A lookback period of several years is an excellent strategy*** to stabilize reservoir storage when flows are increasing or steady with small year-to-year variations. A lookback period is insufficient when flows decrease or are volatile because even one low flow year can push the system from crisis to dead pool.
3. ***We must include reservoir evaporation as the highest priority consumptive use*** to stabilize reservoir storage at low storage. The water available to users becomes river flow minus the evaporation.

Political:

4. ***Colorado River users and the Federal Government may differ on how much reservoir drawdown to allow to augment low flows.*** The allowable drawdown may decrease as reservoir storage declines towards protection elevations.
5. ***There is a tension between planning now*** for extreme low flow and reservoir storage versus delaying decisions until the need is imminent or users have the chance to ramp up their water conservation programs.
6. ***Users with low priorities who face the largest risk of water shortages may want to plan for extreme conditions now*** so they have more predictable supply during crisis.

Ultimately, to stabilize and recover reservoir storage during crisis, we need more adaptive strategies that can quickly mobilize large reductions in consumptive use in anticipation of or response to sudden and large decreases in river flow.

Please email Anabelle Myers (A02369941@usu.edu) and David Rosenberg (david.rosenberg@usu.edu) if you would like to join an upcoming immersive modeling session where you can explore, punch down, or possibly improve more adaptive strategies in a fun, low-stakes, and anonymous space with only a 2-hour time commitment.

Data Availability

The data and code used to generate Figure 1 are available on Github [here](#). The data, code, and models used to generate Figures 2 to 4 are available in the links provided in the text.

This work is funded as part of the National Oceanic and Atmospheric Administration (NOAA) project Immersive modeling to communicate and manage risks of water shortages in the Colorado River Basin. The Utah State University project number is IRB-14808. If you want to reach out to the project lead, you can reach him at david.rosenberg@usu.edu; 435-797-8689.