

Paleoflood Hydrology of the Colorado River System

Deciphering the history of extreme floods from the geologic record

Research Bulletin
Science and Technology Program

S&T Project 1736

This project develops a history of extreme floods in the Upper Colorado River basin using paleoflood information from the geologic record. Paleoflood data improve the estimation of extreme floods, reducing the uncertainty in their magnitude and frequency for flood hazard assessments and long-term planning at Reclamation dams and reservoirs.

Mission Issue

Improved understanding of flood potential leads to effective management of reservoirs during flood events and in long term water planning, which may result in reduced downstream flood damage and greater opportunity for water storage.

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Problem

Our understanding of flood hazard is based upon flood magnitude-frequency curves derived from a short observational period, limiting our knowledge of the potential for extreme flooding. In the southwestern U.S., the gaged and historical record rarely exceeds one hundred years; therefore, large floods are statistically under-represented (Thornycraft et al., 2003).

Despite the powerful application of dendrochronology in the Colorado River basin as an excellent proxy for average annual streamflow, it provides little or no information for reconstructing extreme flood events because floodwaters are conveyed too rapidly across the landscape to allow for significant increases in soil moisture (a primary driver for tree growth).

Paleoflood studies produce flood chronologies that can be used to improve flood-frequency analysis (e.g. Benito and Thornycraft, 2005; Harden, et al., 2015), maximum flood discharge-drainage area relationships (Enzel et al., 1993), and flood-climate linkages (e.g. Macklin and Lewin, 2003; Harden et al., 2010).

Solution

The project focused on the Green River, a major tributary to the Colorado River, and the Colorado River downstream of Lees Ferry, Arizona in order to investigate the magnitude and frequency of floods in the Upper Colorado River Basin (UCRB).

The sequence and ages of flood deposits were described; stage and associated discharges for each flood deposit were modeled using two-dimensional hydraulic models. These data were input into flood frequency analyses along with the systematic gage records to provide updated flood frequency curves. Using the chronological ages from flood deposits and paleoclimate records from sites in the UCRB and elsewhere, linkages between extreme floods and climate patterns were also explored. This provides an understanding of the hydroclimatology that can drive extreme floods in the UCRB.



Location map of study sites in the Upper Colorado River Basin (UCRB). Purple rectangles indicate paleoflood data developed and/or utilized for this project.

“The very real information on the most extreme floods that can be discovered through paleoflood studies offers a preferable alternative to conventional flood-frequency analyses, both for estimating the risks posed by the most extreme flood phenomena and for communicating those risks both to river managers and to the general public.”

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More Information

<https://www.usbr.gov/research/projects/detail.cfm?id=1736>

Application and Results

The detailed investigation into the paleoflood record revealed that extreme floods are much more frequent than the systematic gage record would suggest and highlights the problem with the short length of gaging records. On the Green River, results from paleoflood investigations indicate that extreme floods occur on a much more frequent basis and have greater magnitudes than floods in the systematic record, the largest of which are about two times greater in magnitude than historical floods.

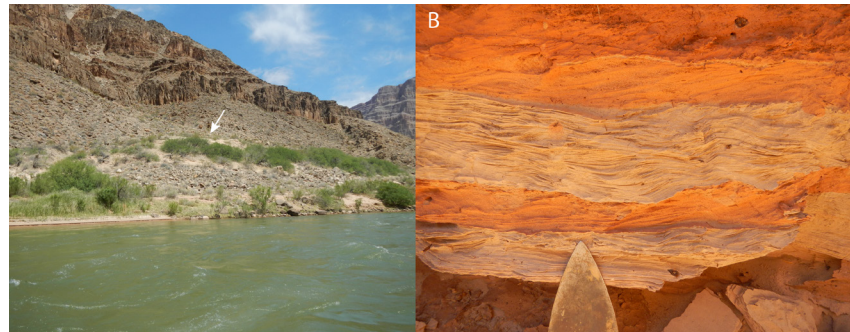
A test using the systematic gage record without the paleoflood data shows that the flood frequency analysis overestimates the return period of extreme floods. In other words, when paleoflood data are incorporated into the flood frequency analysis, the return period of extreme floods, as well as the 100-year flood, is much more frequent. Previous investigations on the Colorado River and new preliminary investigations on the Colorado River in Grand Canyon, Arizona indicate that the peak discharge associated with the highest stage of the slackwater deposits is 1.5-2.5 times larger than the peaks of record in the systematic gage records. By using 77 chronological ages from seven stratigraphic sites of slackwater deposits in the UCRB, several clusters of extreme flood activity are identified: 8040-7790, 3600-3640, 2880-2740, 2330-700 and 620-0 years BP.

Comparison of paleoflood records of extreme floods to paleoclimate records reveal that extreme floods occur in both wet and dry periods. The authors attribute the periods of extreme floods in the UCRB to an increased intensity of storms from the North Pacific that are associated with enhanced ENSO variability. The extreme floods appear to happen less frequently in more stable wet periods or stable dry periods. This research can be applied to water operations and flood hazard assessments in the Upper Colorado River Basin to model the actual frequency of extreme floods and in long term planning in the watershed.

Future Plans

The analyses and conclusions of this study are limited by the relatively small number of paleoflood sites and geochronological ages in the Upper Colorado River Basin. Most of Reclamation’s data on tributaries to the Upper Colorado River are in the form of non-exceedance bounds, which only provide upper limits to flood magnitude.

More locations of paleoflood estimates would further refine the paleoflood history of the Upper Colorado River Basin and our understanding of flood-climate linkages. It is critical to continue the work on the Colorado River downstream of Lees Ferry, Arizona. This specific reach is important because it includes all the drainage area for the major dams and water supply from the Upper Colorado River Basin.



Slackwater deposits along the Colorado River, Grand Canyon. A. Example of a slackwater deposit, top of deposit is shown by white arrow; B. Example of the stratigraphy of flood deposits showing mainstem Colorado River flood deposits (light tan units) interbedded with tributary deposits (reddish-orange units). Photos courtesy of Tess Harden, USGS.