BILL WILLIAMS RIVER, ARIZONA: RESTORING NATURAL VARIABILITY IN AN ARID LANDS RIVER

Andrew Hautzinger

A truism of managing natural systems is that Mother knows best. This is being applied to the management of Alamo Dam to return elements of the natural hydrograph to the Bill Williams River (BWR). This article explores the unique gifts Mother Nature gave to the BWR system, the BWR's natural hydrograph, and why so much work is occurring to manage this river's natural resources. This article also highlights a few tools that have been developed to apply the best of the river sciences to questions about balancing human water needs with the needs of the environment. Finally, it touches upon the importance of having a commitment to experimentation and to monitoring.

The BWR drains over 5,000 square miles of sparsely vegetated (and sparely populated) Arizonan desert country. After the Salt River and Verde River, the BWR watershed is Arizona's largest. The BWR is tributary to the lower Colorado River (LCR) and one of only three perennial tributaries to this section of the Colorado. Much of the interest in the ecology of the BWR stems from the almost complete paucity of functional riparian habitat on the Lower Colorado River (LCR) itself.

Historically, the BWR was primarily used by humans for farming, ranching, and mining. Mr. Bill Williams himself was a beaver trapper who was infamous for going "wild" for long stretches of time, reappearing in town, beaver pelts over his shoulder, when most bets were he'd long since died.

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While the hydrology of the BWR today is very different than it was before 1968 when Alamo Dam was constructed (see Figure 1), for a variety of reasons the river's riparian system has maintained a higher level of natural function than is typical of altered river systems in the American West. This habitat diversity maintains a concomitant and exceptional degree of biodiversity within the LCR. BWR represents about half the acreage of the mature large-stand cottonwood-willow forests left in the LCR (see Figure 2). It supports over 350 bird species, and 11 of the LCR's 34 butterfly species are now only found in the BWR basin. Its upper tributaries have significant native fish populations. This habitat diversity helps maintain a concomitant, exceptional and now unique biodiversity on the LCR. The BWR National Wildlife Refuge has documented over 1,000 species including 56 mammals, 29 fish, 304 plants and fungi, 54 amphibians and reptiles, and 261 invertebrates. Many of these species are no longer found elsewhere on the LCR.

While there are encouraging signs of ecological health on the BWR, the presence of Alamo Dam has dramatically changed fundamental physical and biological processes on the BWR. Based on an analysis of hydrographs generated from available data (BWR has been gauged since the 1890s), the BWR is the poster child of the flashy southwestern river, prone to apocalyptically large floods, followed by months of quiet, dry weather. Statistically, the BWR has been described as being the southwest's "flashiest" watershed (TetraTech, 2002). Looking at the reach below Alamo Dam, the system's geomorphology presents a classic hour-glass land form. Stretches of tight canyon are broken by large flood plains filled at depth with porous sedimentary rock (alluvium). During extended dry periods, there typically is no flow in the BWR in the upstream parts of these floodplains. However, at the lower ends of these floodplains, as the river valley begins to contract from broad floodplain to canyon, water typically reappears, bubbling out of the saturated alluvium to form stretches of perennial flow. Over the river system's lower 40 miles, the system possesses some four to five ephemeral reaches, and a similar number of stretches with fairly dependable perennial flow. Thus, for any given level of base flow in the river system (typical base flow-releases out of Alamo Dam are between 20-50 cfs), any number of flow conditions can be manifested over the 40 river miles below the dam.

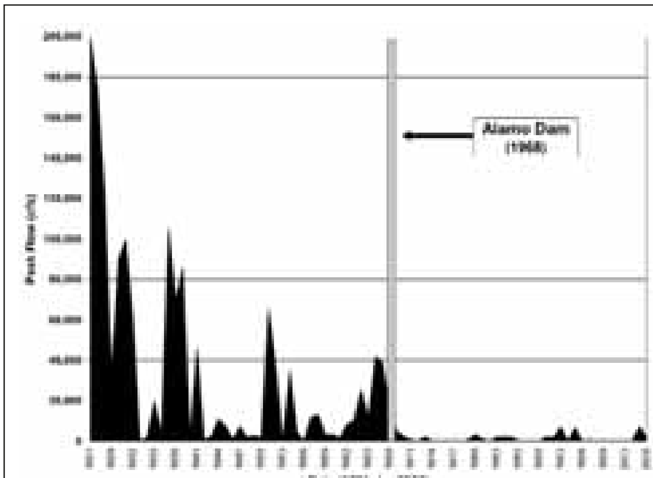

Figure 1. Annual Peak Flows (Bill Williams River, Arizona).

Figure 2. Cottonwood-Willow Gallery (Bill Williams River NWR, Arizona).

Understanding the pattern represented by this river's hydrology is tricky enough, but linking the river's biology to its hydrograph proves even more challenging. Much of the scientific work on the BWR has focused on linking the flow regime (which can be highly controlled with releases from Alamo Dam) to biotic responses and needs. How do low summer flows affect new tree seedlings? How do high flows in the fall impact aquatic organisms? How much of a flood does it take to remove beaver dams? To allow scientists and managers to grapple with these types of questions, much effort has been expended to develop tools to evaluate system response to dam releases. Use of experimental floods (based on the natural hydrograph), has been a fundamental and critical part of this tool development effort.

Tools that have been utilized to model the system have primarily been generated by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC). Models include a one-dimensional hydraulic model with GIS integration capabilities based on Light Detection And Ranging (LIDAR) generated topographic information (HEC-RAS); a reservoir-operations simulation model (RES-SIM); and an integrated physical-biological model in which spatially specific biotic responses are predicted based upon quantitative estimates of ecosystem flow requirements (Ecosystem Functions Model or HEC-EFM) (Shafroth and Beauchamp, 2006). These tools have allowed predictions on the biological relevance of flow events. What flow or range of flows are likely to establish woody riparian seedlings ... or develop and maintained desired aquatic habitat?

The increased accuracy and range of functionality that is associated with today's predictive models has improved our ability to manage complicated natural systems. These tools allow the scientist and the manager to generate much more detailed hypotheses that can then be ground tested for model refinement and calibration. The role of experimental flows is critical in this dynamic: there is no substitute for testing flow-related theories or assumptions with actual flow events.

The scientists and managers working on the BWR have recently conducted a series of experimental releases from Alamo Dam, looking at the pre-dam hydrograph for design guidance. Experimental releases occurred in 2005, 2006, and 2007 with varying goals and objectives. The primary goal associated with the 2005 releases was to evacuate the reservoir after a series of large and sustained storm events filled Alamo Lake with over 400,000 acre-feet during a period of 120 days (breaking a grueling six-year drought). Beyond this flood control objective, a secondary objective was articulated – could the releases be timed and shaped such that the dam releases could mimic the function of natural flows and help to establish a new generation of cottonwood-willow? This successful experiment (many thousands of seedlings established in 2005 have survived into the spring of 2007!), highlighted the usefulness of mimicking elements of the natural hydrograph, most especially in regards to the seasonality of the flow event.

In March 2006 and April 2007, two more experimental releases were conducted (with high flows of 2,000 cfs and 1,000 cfs, respectively). Both of these events were smaller than the 2005 releases (which equaled the dam's maximum release of 7,000 cfs). The 2006 and 2007 events were designed to allow physical and biological observations during flows that occupied the lower end of the system's flood regime. All of the experimental flows had biologic objectives. What would these flows do to newly-repaired beaver dams? What shifts could be observed in the aquatic insect community? While results are still being analyzed, early indication are that both of these flow levels made significant changes in beaver dams (a high percentage encountered significant damage, while a few were washed out completely) and aquatic insect communities (a shift towards more lotic native-dominated taxa directly after flows were observed).

In summary, the experiences on the BWR are similar to work going on around the world, where people are using science to help determine if development and use of water leaves room for protection of flow-dependent wildlife. The work of the BWR team (please go to http://billwilliamsriver.org for more details) has demonstrated that it is critical to look at the natural hydrograph to identify broad ties between flows and the biota. This linking of the hydrograph to the biology forms the cornerstone of achieving environmental goals associated with dams and the like. Our work on the BWR has shown that using experimental flows that mimic some portion of the natural hydrograph is a most effective learning tool.

Finally, not enough emphasis can be placed on the need to have a significant and durable commitment to experimentation and monitoring. With all the advances in river science over the past few decades, we are still limited in our ability to accurately characterize natural dynamics. This is doubly true when we attempt to ameliorate environmental damages caused by human induced changes. As most of the world's river systems are altered by human actions of some sort, it is incumbent upon us to look at pre-altered "natural" conditions to glean those natural processes and functions that we can encourage and facilitate (even in reduced form and scale) to further the goal of environmental benefit. The work discussed in this paper strongly suggests that mimicking parts of the natural hydrograph is a great place to start.

REFERENCES

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AUTHOR LINK Andrew Hautzinger
U.S. Fish and Wildlife Service
Division of Natural Resources
500 Gold Ave. SW, Suite 9016D
Albuquerque, NM 87102
(505) 248-7946 / Fax: (505) 248-7950

E-MAIL andrew_hautzinger@fws.gov

Andrew Hautzinger Andrew holds a B.S. in Watershed Science from Colorado State University (1991). He has worked for the U.S. Fish and Wildlife Service's Region 2 for the last 10 years, as a Regional Hydrologist. He provides water resource and water right support to four national wildlife refuges located in the state of Arizona, along the lower Colorado River. Prior to his work with the USFWS, Andrew was employed with the U.S. National Park Service Water Resources Branch, where he worked on a national scale providing technical support for the national parks. Prior to that, Andrew worked for two years with the U.S. Bureau of Land Management, in Craig Colorado, where he worked closely with energy companies on legal compliance issues.

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