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Leveraging environmental flows to reform water management policy: Lessons learned from the 2014 Colorado River Delta pulse flow

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ABSTRACT

Minute 319, a binational agreement between the United States and México, authorized environmental flows into the Colorado River Delta, including a high-profile pulse flow delivered in March through May 2014. Reforming water management policy to secure future delivery of environmental flows to the delta hinges on demonstrating the feasibility of delivering environmental water and documenting positive ecological responses of the delta's severely degraded riparian habitat. The design of the flow's hydrograph, the novel utilization of irrigation infrastructure, the preparation and subsequent maintenance of selected restoration sites, and interdisciplinary monitoring at multiple scales combined to show that ecological restoration is possible, even with extremely small water volumes compared to historical flows. The overwhelmingly positive social responses to the flow are likely as pivotal to future flows as are the biophysical responses. The pulse flow's unique binational character demanded exceptional collaboration and communication involving local, state, and federal government agencies; water managers; water users; scientists; and non-governmental organizations. The success of such a politically, operationally, and scientifically complex endeavor in the severely over-allocated Colorado River Basin bodes well for the future of environmental flows in its delta and in other water-stressed settings, worldwide.

1. Introduction

On November 20, 2012, Minute No. 319 (Minute 319): Interim International Cooperative Measures in the Colorado River Basin (IBWC, 2012) authorized the world's first environmental flow release across an international boundary. A total of 195 million cubic meters (Mm^3) of water was allocated to the Colorado River Delta over the five-year term (2013–2017) of the Minute (IBWC, 2012). A coalition of nongovernmental organizations (NGOs) agreed to provide 65 Mm^3 of water for low-magnitude habitat maintenance flows (termed "base flow" in the Minute) over the five years, while the United States (U.S.) and México provided a one-time delivery of 130 Mm^3 (105,000 acre-feet; AF) as a "pulse flow." From March 23 through May 18, 2014, the pulse flow water was released into the Colorado River, along and then across the international border between the U.S. and México. The pulse flow provided a rare opportunity to assess the potential for environmental flows to restore the delta's severely degraded riparian habitat.

Diversions from the Colorado River and its tributaries supply water to almost 40 million people, irrigate more than 5.5 million acres of land, and produce more than 4200 megawatts of hydropower (U.S. Department of the Interior, 2012). Forty-five percent of the Colorado's water is diverted out of its basin (Western Resource Advocates, 2003).

Prior to the construction of dams and diversions, the river carried water, sediment, and nutrients into its sun-drenched delta, creating exceptionally productive complexes of wetlands and forests (MacDougal, 1906; Sykes, 1937), which comprise a critical pinch point on the Pacific migratory bird flyway (Hinojosa-Huerta et al., 2007). In addition, flows from the river supported marine

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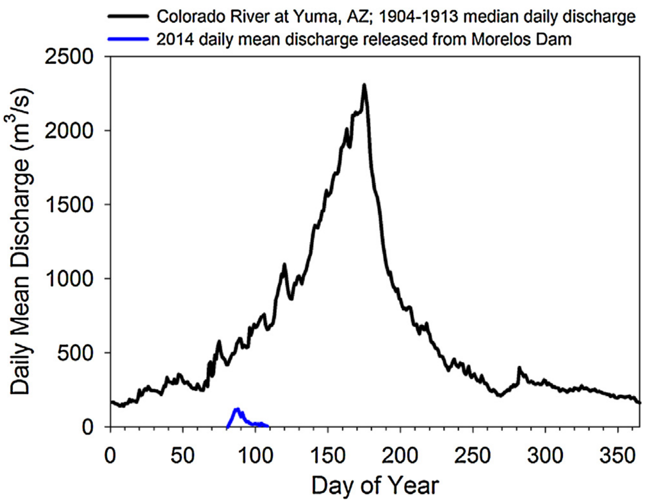

Fig. 1. Comparison between median daily mean discharge for the Colorado River at Yuma, Arizona, for the period 1904–1913 and daily mean discharge released from Morelos Dam during the 2014 pulse flow (Mueller et al., 2016).

productivity in the upper Gulf of California (Sea of Cortez) (e.g., Calderon-Aguilera and Flessa, 2009; Galindo-Bect et al., 2000; Kowalewski et al., 2000).

By the 1970s, river flows to the delta had been reduced to such an extent that bare ground and invasive saltcedar had replaced most of the native riparian vegetation, and the river rarely met the sea (Glenn et al., 1996). Today, the 100 kilometers (km) (60 miles) of levee-flanked riparian corridor between the Mexican border and the Gulf consists of saltcedar-choked floodplains; long reaches of dry, sandy river channel; and widely spaced remnants of native willow (*Salix gooddingii, S. exigua)* and cottonwood *(Populus fremontii)* stands flanking sluggish pools fed by shallow groundwater. Outside the levees, the last diversions of Colorado River water irrigate Mexicali Valley's highly productive cropland.

Minute 319 is a five-year (2013–2017) agreement that changes how the U.S. and México share water shortages and surpluses, allows México to store water in Lake Mead, facilitates the repair and improvement of Mexicali Valley's irrigation infrastructure, and authorizes the environmental flows discussed here. It is a "package deal"; the need for environmental flows alone would not have resulted in an agreement to provide them (King et al., 2014; Stanger, 2013; Wolf, 2005).

The prescribed environmental flows were intended to emulate the ecological functions of natural floods and base flows of snowmelt-driven riparian systems, upon which the germination and survival of the native cottonwood and willow species depend. Prior to dam construction, spring snowmelt from the Colorado River basin scoured the delta's streambanks and floodplains, deposited nutrient-rich sediment, and sustained the moist soil conditions and groundwater levels required by these native riparian trees. The Minute 319 pulse flow tested whether an intentionally released flow of 130 Mm^3 (105,000 AF) could serve these functions, despite its diminutive magnitude compared to historical floods (Fig. 1).

A binational, interdisciplinary "pulse flow team" of stakeholders, water managers, engineers, scientists, and other experts designed and implemented the 2014 pulse flow and monitored its hydrologic, ecological, and social responses. The team included officials from the U.S. Department of Interior Bureau of Reclamation, México's National Water Commission (CONAGUA), U.S. and Mexican Sections of the International Boundary and Water Commission (IBWC), a binational Environmental Flows Team, and a binational Science Team (Pitt and Kendy, this issue). Together, the pulse flow team members acquired information "to inform future decisions regarding binational cooperative efforts to address proactive actions in the Colorado River Delta," as mandated in Minute 319 (IBWC, 2012, p. 12). Although the term of the Minute was only five years, it could potentially set a precedent for future water allocations for environmental flows to the delta.

Environmental flows are new to the delta, but not to the world. For several decades, water managers have been experimenting with new ways to operate water infrastructure such as dams and diversions in response to changing values. For example, dams were originally built for flood protection, water storage, hydropower, and recreation. With growing societal awareness of adverse environmental impacts, dam releases are also increasingly being used to mitigate those impacts and to improve the health of downstream ecosystems (Poff and Schmidt, 2016; Tharme, 2003; Annear et al., 2004).

Environmental flow releases are not even new to the Colorado River. That precedent was set by the 1996 release of water from Glen Canyon Dam to benefit riparian habitat and recreation in Grand Canyon National Park (Webb et al., 1999). As Schmidt et al. (1999) discuss, the flow itself was preceded by many years of negotiations and discussions among scientists, agencies and environmental groups. Subsequent releases have explored the ways in which dam operations can benefit downstream habitats without undue impacts on power generation. An impressive body of knowledge about sediment transport, riparian vegetation, and native fish has accumulated, allowing for adaptive management of the physical and biological resources of Glen Canyon and the Grand Canyon (e.g., Patten and Stevens, 2001; Gloss et al., 2009; Melis, 2011). Continuing environmental flows – termed "High Flow Experiments" – and downstream monitoring have become institutionalized through the formation of the Grand Canyon Monitoring and Research Center (GCMRC, 2017). The controlled releases from Glen Canyon Dam, begun in 1996, and the research on their downstream effects, have produced valuable policy-relevant science on how best to integrate traditional water management for power and consumptive use with management for ecosystem services.

Similarly, since the early 1990s, land and water managers along the Bill Williams River, a tributary to the Colorado, have collaboratively managed flow releases from Alamo Dam. Iterative modeling and experimental flow releases since 2006 are contributing to adaptive flow management on the Bill Williams River and to the development of regional environmental flow standards (Shafroth et al., 2010).

While several authors have reviewed methods for determining environmental flow needs (e.g., Tharme, 2003; Annear et al., 2004; Linnansaari et al., 2013), few retrospective assessments of the ability of environmental flows to achieve ecological and policy outcomes have been conducted. Based on their review of 156 papers, Davies et al. (2014) emphasized the need to establish flow-ecology hypotheses and design flow releases and monitoring programs to test those hypotheses for adaptive management. Acreman et al. (2014) asserted that environmental flow science supports all aspects of the policy cycle, from objective setting to legal and institutional reform. By analyzing 113 environmental flow experiments, Olden et al. (2014) and Konrad et al. (2011) identified common characteristics of flow experiments that successfully influenced water management policies.

In this paper, we build upon this body of work by describing key lessons learned from the management, monitoring, and reporting of the 2014 Colorado River Delta pulse flow. We frame these lessons in the context of influencing future water management for flow deliveries into the Colorado River Delta and elsewhere.