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Planform channel dynamics of the lower Colorado River: 1976–2000

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Abstract

In the past two decades, major flood events have occurred on the lower Colorado River, a dramatic shift from the low flows and moderate floods associated with prior decades of river regulation. This study uses repeat aerial photography and Geographic Information System analysis to examine the planform channel response of the upper Colorado River delta (limitrophe reach) to this recently altered hydrology. Results indicate that channel contraction has been the dominant planform process in recent decades, but periodic floods resulted in channel expansion (1981–1988; 1997–2000) or likely reduced the channel contraction measured between successive aerial photographs (1976–1981; 1988–1994). Sinuosity adjustments were limited during the timeframe of the study (range: 1.31 to 1.38), but the channel did respond with large adjustments in channel width (range: 44 m to 355 m) and changes in total mid-channel bar area (range: 0 to 52.3 ha). A channel probability model developed for this study provides a raster image of the channel changes and depicts areas modified to varying degrees by flood flows. This historical study provides insight into how floods affect the channel system that provides the foundation for aquatic and riparian biodiversity. This issue is of increasing relevance given growing international interest in rehabilitating the riparian and aquatic ecosystems of the Colorado River delta through intentional flood flows.

Keywords: Channel change; Regulated river; Colorado River delta; River restoration; GIS

1. Introduction

Understanding the planform dynamics of river channels has important implications for maintaining biodiversity (Naiman et al., 1993; Hughes, 1997; Ward et al., 1999) and minimizing flood damage (Holburt, 1984). In recent decades, the lower reaches of the highly regulated Colorado River experienced episodes of intense flooding in response to major precipitation events. This represented a significant change from earlier regulated decades, characterized

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by fewer and smaller floods (Graf, 1985). Although these recent floods incidentally rehabilitated large areas of ecologically important riparian vegetation (Glenn et al., 1996, 2001; Stromberg, 2001; Tiegs et al., in press), they caused property damage nearing $100 million (Holburt, 1984). Investigations of historical channel change provide insight into how stream channels respond to such flood events. With this information, land and resource managers are able to make decisions that minimize social costs (e.g., flood damage to property) and maximize the ecological benefits of flooding (e.g., rehabilitating riparian vegetation and deterring the proliferation of exotic species).

Aerial photographs provide useful historical data that can be used to explore geomorphic change (Trimble and Cooke, 1991), including the dynamics of fluvial landforms. In recent decades, researchers exploited GIS (geographic information systems) to enhance the utility of aerial photographic data (e.g., Gurnell et al., 1994, 1998; Graf, 2000; Winterbottom, 2000). A benefit of GIS over manual techniques is the ability to register photographs to a common base yielding a collection of time-series mosaics at the same scale (Graf, 2000). With such methods, researchers can readily quantify channel changes through time.

Given the constantly changing character of fluvial systems, Winterbottom (2000) notes the importance of discerning between gradual changes occurring within fluvial systems in a state of dynamic equilibrium and alterations in channel form and pattern (e.g., sinuosity, braiding index) that constitute a departure from equilibrium. The research presented here focuses on this latter type of change on the lower Colorado River from 1976 to 2000.

Using repeat aerial photography managed in a GIS, our research examines responses of channel width, area, pattern, and sinuosity to episodes of widely fluctuating stream discharge. Additionally, we constructed a locational probability model similar to that of Graf (2000) to determine the most likely configuration of the stream channel during the timeframe of our research. This model can also be utilized to anticipate the location and configuration of future stream channels given similar flow and sediment regimes and land use.

This fundamental geomorphic information has particular utility on the lower Colorado River where flood discharges intended to rehabilitate aquatic and riparian ecosystems have been proposed. However, restoration cannot proceed without a sound understanding of the type and magnitude of channel response that can be expected from flood flows, as well as where such changes will occur. This study provides the historical, geomorphic context needed to discuss desired changes to the form, and function of the lower Colorado River.

2. Study area

We conducted this research on a length of the Colorado River referred to as the limitrophe reach (Cohen et al., 2001). The limitrophe reach is a 30-km length of the lower Colorado River that functions as the political boundary between Arizona (United States) and Baja California (Mexico). Here the river flows from Morelos Dam to the Southern International Border (Fig. 1). The limitrophe reach also constitutes the uppermost limit of the Colorado River delta. We selected this study area for several diverse reasons. First and foremost, this reach is the site of proposed flood discharges intended to rehabilitate riparian vegetation (International Boundary and Water Commission, 2000). Given the close relationship between riparian vegetation and fluvial geomorphic processes (Hupp and Osterkamp, 1985, 1996; Stromberg, 2001), a better understanding of channel response to varying discharges at the limitrophe reach assists resource managers in tailoring a flow regime to rehabilitate native riparian vegetation. Second, the Colorado River is similar to most large rivers in the world in that it is regulated (Nilsson and Berggren, 2000). As such, knowledge generated by this research applies to a large number of rivers that could benefit ecologically and geomorphically from more naturalized flow regimes (i.e., a flow regime that more closely approximates the pre-regulation condition [see Poff et al., 1997 and Rhoades et al., 1999, for discussions of flow regimes and naturalization, respectively]). Third, the availability of aerial imagery and the low relief topography of the limitrophe reach make this area well suited to GIS analysis. Initially, the entire limitrophe reach was to be included in this research. Since aerial photographs of the downstream portion of the limitrophe reach (~6 km) were unavailable, we excluded this section from the study (Fig. 1).