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Post-project geomorphic assessment of a large process-based river restoration project

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ABSTRACT

This study describes channel changes following completion of the Provo River Restoration Project (PRRP), the largest stream restoration project in Utah and one of the largest projects in the United States in which a gravel-bed river was fully reconstructed. We summarize project objectives and the design process, and we analyze monitoring data collected during the first 7 years after project completion. Post-project channel adjustment during the study period included two phases: (i) an initial phase of rapid, but small-scale, adjustment during the first years after stream flow was introduced to the newly constructed channel and (ii) a subsequent period of more gradual topographic adjustment and channel migration. Analysis of aerial imagery and ground-survey data demonstrate that the channel has been more dynamic in the downstream 4 km where a local source contributes a significant annual supply of bed material. Here, the channel migrates and exhibits channel adjustments that are more consistent with project objectives. The upstream 12 km of the PRRP are sediment starved, the channel has been laterally stable, and this condition may not be consistent with large-scale project objectives.

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1. Introduction

The practice of stream restoration has grown substantially during the past several decades to become a multimillion dollar industry on many continents (Bernhardt et al., 2005; Wohl et al., 2015). Projects to restore or rehabilitate rivers and streams include a wide range of activities from the reach to the watershed scale, including reestablishment of native riparian vegetation (Osborne and Kovacic, 1993), release of controlled floods (Webb et al., 1999; Flessa et al., 2013), construction of in-channel structures (Rosenfeld et al., 2010), additions of large woody debris (Rosenfeld et al., 2010; Lassettre and Kondolf, 2012) or coarse substrate (Miller et al., 2010), channel realignment that involves substantial earth moving (Kondolf et al., 2001; Smith and Prestegaard, 2005), removal of large dams (Major et al., 2012; East et al., 2015), and multifaceted basin-scale watershed rehabilitation programs (Whalen et al., 2002; DiGennaro et al., 2012).

Despite substantial investment in such projects, however, there has been a conspicuous absence of post-project monitoring and thus limited learning from project successes and failures (Kondolf and Micheli, 1995; Bash and Ryan, 2002; Kondolf et al., 2007; Bernhardt and Palmer, 2011; Roni et al., 2013; Wohl et al., 2015). In a survey of >37,000 river restoration projects, Bernhardt et al. (2005) found that only 10% of projects included some type of post-project monitoring or assessment. Inadequate funding for monitoring contributes to the lack of post-project evaluation, but the limited number of rigorous analyses of project performance also results from the vague goals of many projects, project management that often places little value on post-project monitoring, and application of ineffective monitoring metrics; in other cases, monitoring data and analyses exist but remain unpublished (Roni et al., 2008). Published analyses of post-project monitoring data that extend for many years and cover the full project extent are needed (Downs and Kondolf, 2002; Palmer and Bernhardt, 2006; Roni et al., 2013) in order to distinguish short-term from long-term, and small-scale from large-scale, channel and ecosystem change.

The need for additional monitoring data over longer time frames and larger spatial scales is especially acute when it comes to the assessment of projects that employ a process-based design strategy. The research community has repeatedly asserted the need to emphasize restoration of river function or process rather than focusing on form (Wilcock, 1997; Kondolf, 1998; Wohl et al., 2005; Simon et al., 2007; Bernhardt and Palmer, 2011). When monitoring the geomorphic performance of a project designed to recreate or attain a specific form, monitoring may simply entail assessment of whether as-built structures or topography match the design and whether these features remain in the condition in which they were built. In contrast, monitoring and assessing the performance of process-based designs requires evaluating systems designed to evolve and to distinguish between post-project channel change that involves negative, or positive, feedback mechanisms; thus, assessment of geomorphic performance necessitates measuring and evaluating the style, magnitude, and rate

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of geomorphic change occurring in the restored river for many years after a project is completed.

This paper describes the objectives, design strategy, and post-project channel change of the Provo River Restoration Project (PRRP), the largest river restoration project in Utah and one of the largest projects in the United States to entail the complete reconstruction of a gravel-bed, alluvial river. The PRRP, located downstream from Jordanelle Dam, was implemented as mitigation for the construction of the dam and associated water development infrastructure. The project involved the removal of levees, construction of a new channel, and construction of floodplain habitats along a 16-km segment of river. We sought to monitor the evolution of channel morphology in the PRRP at the scale of pool-riffle complexes and along the entire length of the reconfigured channel to document post-construction adjustments in channel form at small and large scales.

Here, we report on channel changes documented during the first 7 years following construction. Our findings demonstrate the value of a multiyear, large-scale monitoring program. The upstream 12 km of the PRRP are sediment starved, the channel has been laterally stable, and present conditions may not be consistent with project objectives. In contrast, the downstream 4 km of the PRRP receives a significant annual supply of bed material from a local source and the style of channel adjustments observed are more consistent with project objectives. Additionally, we show that there were two phases of post-construction adjustment in the downstream segment of the PRRP: (i) a period of rapid adjustment immediately following channel construction and (ii) a period when the channel changed gradually, transitioning toward a self-adjusting river that migrates laterally across its floodplain.

2. Background

2.1. Study area: the Provo River, Utah

The Provo River flows ~110 km from its headwaters in the Uinta Mountains southwest to its outlet into Utah Lake. The PRRP is located on the section referred to as the middle Provo River, where the river flows through the formerly agricultural and increasingly exurban Heber Valley (Fig. 1). The drainage area to the PRRP is ~930 km^2. Prior to significant water development, the mean peak flow and mean annual

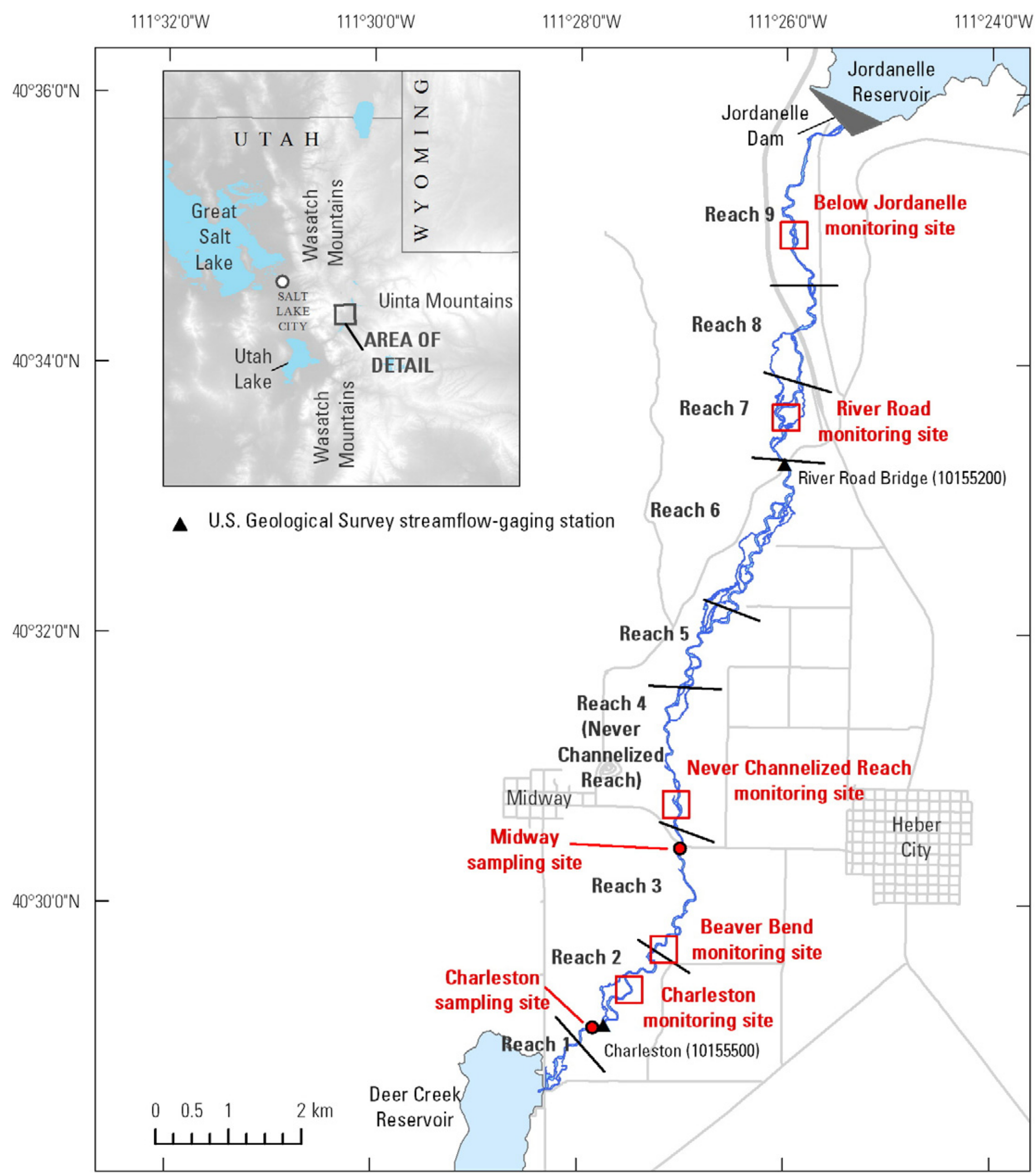

Fig. 1. Map of the Provo River Restoration Project (PRRP), located in Heber Valley, Utah. Flow is from top to bottom, from the outlet of Jordanelle Dam to Deer Creek Reservoir. Reaches 1 to 3 correspond to the Downstream PRRP; reach 4 is the Never Channelized Reach; and reaches 5 through 9 correspond to the Upstream PRRP.