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Influence of four run-of-river dams on channel morphology and sediment characteristics in Illinois, USA

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ABSTRACT

Dams are known to create discontinuities in river flow and sediment transport, with ensuing effects on the fluvial geomorphology of dammed systems. While the effects created by large impoundment dams are well documented, less is known about the influence of small run-of-river dams (common across the eastern United States) on river geomorphology. Recent emphasis on dam removal has focused on run-of-river structures, highlighting the need for improved understanding of the geomorphological effects of these types of dams. This research examines spatial variation in channel morphology and bed sediment character upstream and downstream of four run-of-river dams in Illinois. Results show that the four dams do not create major discontinuities in channel morphology or sediment character. Silt/clay content of bed material at the four sites is higher upstream of the dams than downstream, but this size fraction generally is a minor component by weight of the sediment samples collected. Although percentages of sand are generally higher upstream of the dams and gravel percentages are generally higher downstream, not all of these differences are statistically significant. Longitudinal profiles through the dams and changes in channel depth upstream and downstream of the dams indicate that no major accumulations of sediment have occurred behind the dams. Analysis of ^{137}Cs in sediment cores at two sites shows no evidence of long-term fine sediment storage. Apparently, these dams are not acting as major sediment traps, nor do these structures produce substantial downstream channel erosion. Variability in spatial patterns of channel morphology and sediment characteristics among the sites suggests that local site-specific factors have an important influence on geomorphological responses. Because of this variability, the findings of this study indicate that information on site-specific conditions should be an important consideration in the removal planning process for run-of-river dams.

1. Introduction

Large dams – by acting as barriers to flow, sediment, and aquatic organisms – can create major discontinuities in river geomorphological and ecological conditions (Christiansson, 1979; Kashef, 1981; Galay, 1983; Petts, 1984; Williams and Wolman, 1984; Chien, 1985; Neil and Mazari, 1993; Baish et al., 2002; Morita and Yamamoto, 2002; Sethi et al., 2004; Graf, 2005; Lorang and Aggett, 2005; Burdick and Hightower, 2006; Graf, 2006; Orr et al., 2006). By impounding water, large dams lead to the deposition of sediment within the upstream reservoir. Meanwhile, the release of sediment-starved flow from the reservoir typically leads to pronounced erosion, scour, and channel incision downstream (Christiansson, 1979; Kashef, 1981; Galay, 1983; Neil and Mazari, 1993; Kondolf, 1997; Baish et al., 2002; Graf, 2005). Over time, net decreases in flow downstream often result in channel narrowing and expansion of the floodplain, onto which vegetation encroaches (Baxter, 1977; Williams and Wolman, 1984; Benn and Erskine, 1994; Brandt, 2000). Degradation downstream of a dam persists spatially until the quantity of sediment eroded and entrained from the banks and bed becomes equal to the sediment transport capacity of the flow (Petts, 1984; Williams and Wolman, 1984; Chien, 1985).

Although the effects of large dams on rivers are well documented, many dams are small run-of-river structures, also known as weirs or overflow dams, which typically have heights that do not surpass those of the channel banks (Born et al., 1998; Shafroth et al., 2002; Csiki and Rhoads, 2010). Run-of-river dams, a term frequently used by the applied river management community, confine water between the channel banks upstream and allow flow to pass over the crest of the structure unimpeded (Csiki and Rhoads, 2010). Large dams, by contrast, create impoundments that completely inundate the river channel and floodplain upstream of the structure even at low flow stages. Although the influence of large dams on river morphology has been studied extensively, the geomorphological effects of run-of-river dams are poorly understood (Csiki and Rhoads, 2010). Past studies report considerable variability in sedimentation upstream of run-of-river

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dams (Lindloff, 2003; Wildman and MacBroom, 2005; Orr et al., 2006) and whether or not extensive channel erosion related to the effect of sediment-starved water occurs downstream from run-of-river dams has yet to be ascertained. Overall, the extent to which run-of-river dams produce discontinuities in river geomorphology, expressed in changes in channel morphology and bed material characteristics upstream and downstream of these dams, is unclear (Csiki and Rhoads, 2010).

The need for improved understanding of how run-of-river dams affect physical attributes of rivers is of considerable practical importance, given the growing interest in dam removal, which is expected to continue into the future. Run-of-river dams have increasingly been targeted for removal, especially since the 1990s. This trend is driven primarily by public safety concerns (run-of-river dams are often referred to as drowning machines) and increased risk of failure because of deterioration (Baish et al., 2002; Johnson and Graber, 2002; Pohl, 2002). Effective management of removal requires sound scientific knowledge of the effects that these types of structures have on river geomorphology and sedimentology (Pejchar and Warner, 2001; Doyle et al., 2005; Graf, 2005). Such knowledge will help guide decision making about the potential responses of river systems to the removal of run-of-river dams.

This paper examines spatial variation in characteristics of channel morphology and bed material upstream and downstream of four run-of-river dams in Illinois, USA. The purpose is to ascertain the extent such dams produce discontinuities in channel form and sediment characteristics similar to those observed for impoundment dams. While the exact year of installation of each of the structures is unknown, all of these dams were constructed between 1910 and 1930 and therefore have been in place for similar lengths of time, and all are located in watersheds with similar physiographic characteristics and land use. Results inform the extent to which run-of-river dams produce

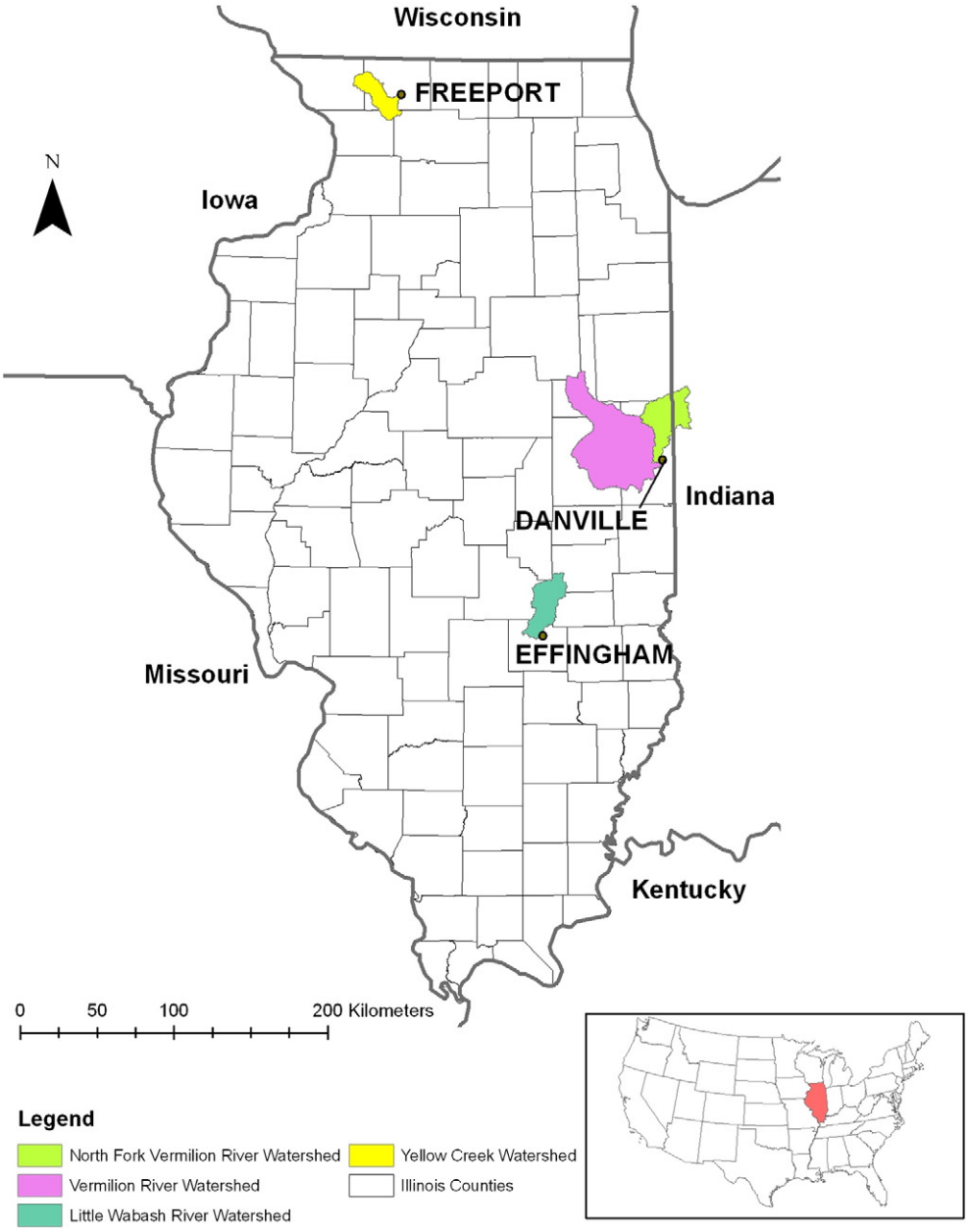

Fig. 1. Locations of watersheds upstream of four run-of-river dams in Illinois.