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Assessment of chevron dikes for the enhancement of physical-aquatic habitat within the Middle Mississippi River, USA

Jonathan W.F. Remo [a,*], Anish Khanal [b], Nicholas Pinter [c]

[a] Department of Geography and Environmental Resources, Southern Illinois University, Carbondale, IL 62901, USA
[b] Department Civil and Environmental Engineering, Southern Illinois University, Carbondale, IL 62901, USA
[c] Department of Geology, Southern Illinois University, Carbondale, IL 62901, USA

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SUMMARY

Blunt-nosed chevron dikes, a new invention now being widely constructed on the Middle Mississippi River (MMR), have been justified as a tool for enhancing physical-aquatic habitat. Chevron dikes were initially designed to concentrate flow, induce channel scour, and thus facilitate river navigation. More recently, these structures have been justified, in part, for promoting habitat heterogeneity. The ability of chevrons to create and diversify physical-aquatic habitat, however, has not been empirically evaluated. To assess the ability of chevrons to create and diversify physical-aquatic habitat, we compiled hydrologic and geospatial data for three channel reference conditions along a 2.0 km (~140 ha) reach of the MMR where three chevrons were constructed in late 2007. We used the hydrologic and hydraulic data to construct detailed 2-D hydrodynamic models for three reference condition: historic (circa 1890), pre-chevron, and post-chevron channel conditions. These models documented changes in depths and flow dynamics for a wide range of in-channel discharges. Depth-velocity habitat classes were used to assess change in physical-aquatic habitat patches and spatial statistical tools in order to evaluate the reach-scale habitat patch diversity.

Comparisons of pre- and post-chevron conditions revealed increases in deep to very deep (>3.0 m) areas of slow moving (<0.6 m/s) water downstream of these structures under emergent flow conditions ($\leqslant 1.5 \times$ mean annual flow [MAF]). Chevron construction added up to 7.6 ha of potential over-wintering habitat (deep [>3.0 m], low velocity [<0.6 m/s]). Chevron construction also created some (0.8–3.8 ha) shallow-water habitat (0–1.5 m depth with a 0–0.6 m/s velocity) for flows $\leqslant 2.0 \times$ MAF and contributed to an 8–35% increase in physical-aquatic-habitat diversity compared to pre-chevron channel conditions. However, modeling of the historic reference condition (less engineered channel, circa 1890) revealed that the historical physical-aquatic-habitat mosaic consisted of a wider and shallower channel with: 45–390% more shallow-water habitat (2.4–11.0 ha) and 22–83% more physical-aquatic-habitat diversity, but little over-wintering habitat (<0.4 ha). Thus, while chevron construction increased over-wintering habitat, shallow-water habitat, and physical-aquatic-habitat diversity relative to the pre-chevron channel condition, these types of physical-aquatic habitat are different from what was historically found along this reach.

Constructing chevrons dikes, or other dike-like structures in the river channel, can change the physical-aquatic habitat patch mosaic and likely contribute to small increases in physical-aquatic-habitat heterogeneity. However, differences in the types, quantity, and diversity of physical-aquatic-habitat patches created by chevron dikes in comparison to the physical-aquatic-habitat patch mosaic of historic channel underscore the need for additional research to determine which physical-aquatic-habitat patches are critical for the recovery of endangered or threatened aquatic organisms.

1. Introduction

For over 175 years, river training structures have been the principal tool for establishing and maintaining the navigation channel along the Middle Mississippi River (MMR; Fig. 1). Three primary types of training structures have been used: wing dikes, bendway weirs and, recently, chevron dikes (Fig. 2). Wing dikes are constructed perpendicular or sometimes oblique from the river bank to direct flow in to the deepest part of the channel (the navigation channel). Under some conditions, wing dikes also trap sediment and constrict the channel. Bendway weirs were invented by the St. Louis District of the U.S. Army Corps of Engineers (USACE) in the 1980s and were constructed in large numbers during the early

* Corresponding author. Address: Department of Geography and Environmental Resources, Southern Illinois University, Carbondale, 1000 Faner Drive, Carbondale, IL 62901-4514, USA. Tel.: +1 618 453 6021; fax: +1 618 453 6465.
E-mail address: diamict@siu.edu (J.W.F. Remo).

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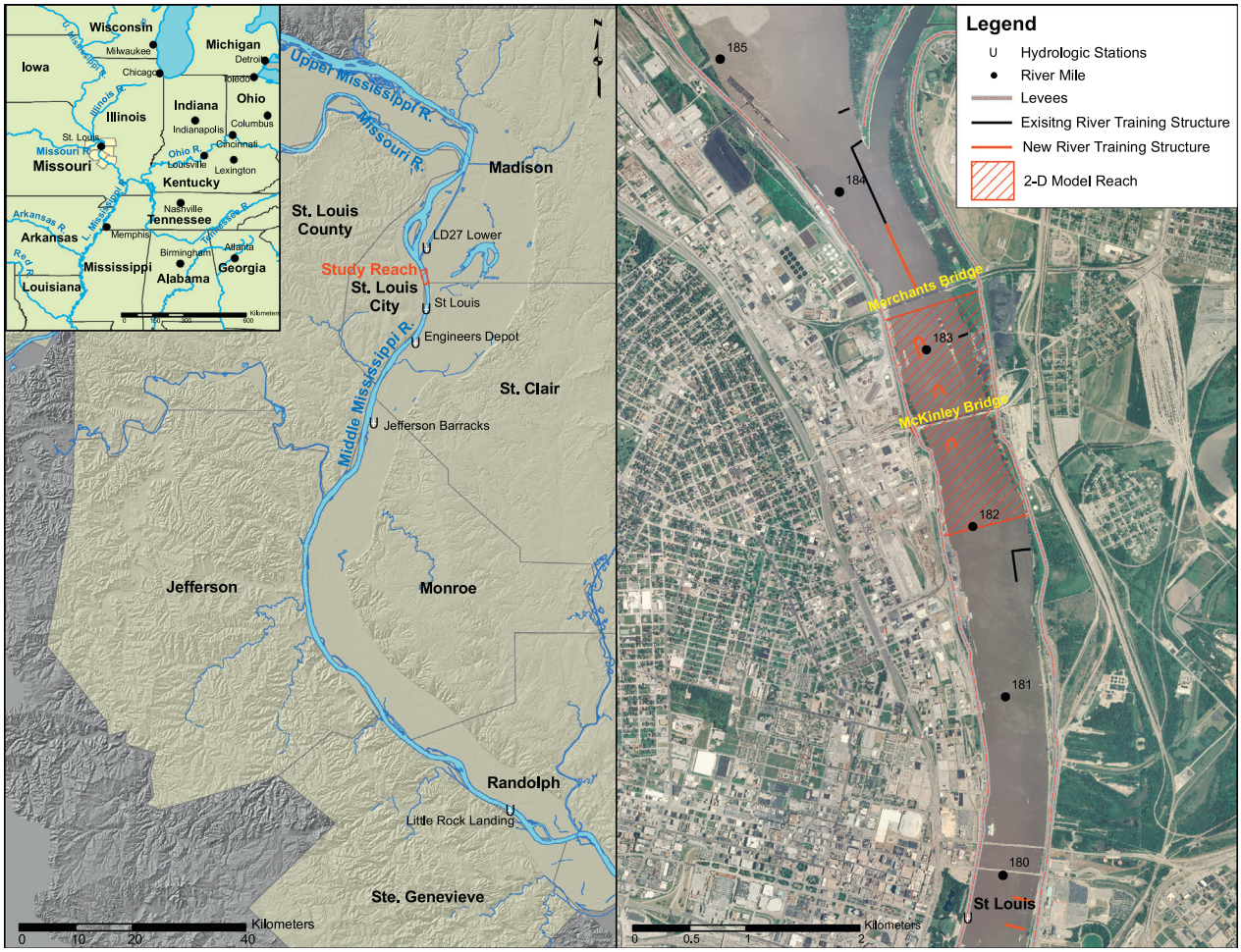

Fig. 1. St. Louis harbor study reach, showing the location of hydrologic stations, river-training structures, and the 2-D hydraulic model domain. All bathymetric, topographic, and velocity measurements for the 2-D hydraulic model were collected within the 2-D hydraulic model domain outlined by the red box. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

1990s. Bendway weirs are submerged stone structures used to maintain required depths within bends (Davinroy, 1990; USACE, 2006). Starting in about 2001, horseshoe-shaped rock dikes, called chevron dikes, have been constructed along portions of the Mississippi River to further deepen the navigation channel and reduce dredging requirements (Gordon, 2004).

River training structures (chiefly wing dikes to date) employed along the MMR have simplified channel morphology and reduced aquatic habitat diversity (USGS, 1999). Habitat loss has been identified as one of the potential factors for the decline of pallid sturgeon *(Scaphirhychus ablus)* within the navigable rivers of the Upper Mississippi River Basin (UMRB; Hurley et al., 2004; U.S. Fish and Wildlife Service [USFWS], 2000). However, newly designed river-training structures, such as chevron dikes, purportedly enhance physical-aquatic habitat heterogeneity and provide needed habitat niches for pallid sturgeon and other aquatic organisms (Fig. 2; Davinroy, 1996; Davinroy et al., 2011a; Ecological Specialists Inc., 1997; Gordon, 2004; Theiling, 1995; USFWS, 2000).

The claims that chevron dikes enhance physical-aquatic habitat and heterogeneity have been neither confirmed nor quantified. Here we employ 2-D hydrodynamic modeling and reach-scale-habitat metrics to assess changes in physical-aquatic habitat and its heterogeneity for pre-chevron and post-chevron conditions along a 2-km reach of the MMR (Fig. 1). In addition, a historic reference condition (circa 1890) was also modeled to compare and contrast differences in physical-aquatic habitat between a less engineered river channel and the new physical-aquatic-habitat patches created by chevron dike projects. This modeling approach quantified changes in habitat availability and diversity among selected reference conditions for a wide range of in-channel flows.

For the historic reference condition, we used retro-modeling methods. Retro-modeling uses archival hydrologic and geospatial data in state-of-the-art models (Remo and Pinter, 2007). Another example of retro-modeling used as a proxy for physical-aquatic-habitat reference conditions is Jacobson and Galat's (2006) assessment of shallow-water habitat along the portions of the Lower Missouri River. Using 2-D hydraulic modeling of the historic and modern channel systems, Jacobson and Galat (2006) found the shallower and wider historical (1894) channel provided 3–7 times more shallow-water habitat than the modern channel, which has been highly engineered to create a narrow and deep navigation channel.

1.1. Background

Recent emphasis on increasing physical-aquatic-habitat diversity, shallow-water habitat, and over-wintering habitat along the MMR stems from the 2000 U.S. Fish and Wildlife Service's Biological Opinion that the operation and maintenance of the navigation channel were threatening the endangered pallid sturgeon. The opinion identified the loss and degradation of aquatic habitat, such as spawning substrate, larval, and juvenile rearing habitat and sea-