Curves, Confluences, and Cutoffs: Morphodynamic insights from the Wabash River

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Overview

Over the past 12 years, a series of research projects has examined the dynamics of confluences, bends, and cutoffs along the Wabash River – one of the largest unregulated meandering rivers in the US. These process-based field investigations have employed a range of methods, including acoustic Doppler current profiling (ADCP), multibeam echo sounding (MBES), ground penetrating radar (GPR), terrestrial laser scanning (TLS), and sediment sampling and coring. This poster provides a brief summary of some of the key findings from these various projects and offers suggestions for future research aiming to improve our understanding of the dynamic processes of meandering rivers.

The Wabash River Basin

The Wabash River is a major tributary to the Ohio River, stretching over 800 km in length and draining an area of more than 100,000 km^2. Aside from a few locations where bedrock is exposed in the channel bed and banks, the majority of the Wabash River freely meanders through its own alluvial floodplain, making it an ideal natural laboratory to conduct research on fluvial morphodynamics.

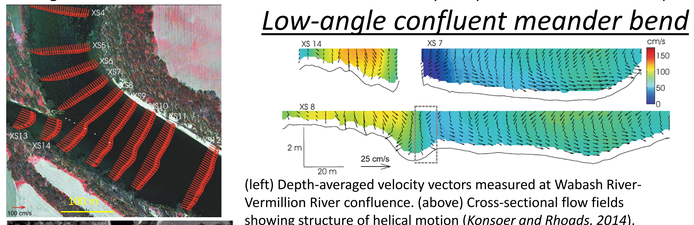
Select locations of previous and on-going research projects in the Wabash basin. 1) Mackey Bend Cutoff and Wabash-Ohio confluence. 2) Series of meandering bends near Grayville, IL. 3) Wabash-White confluence at Mt. Carmel, IL. 4) Wabash-Embarras confluence. 5) Wabash-Vermillion confluence near Cayuga, IN.

Bed material is primarily coarse sand and fine gravel. Near the confluence with the Ohio River, the Wabash River has bankfull width and depth of roughly 350 m and 10 m, respectively, and has a mean annual discharge of ~825 m^{3}s^{-1} (*Zinger et al., 2013*). Farther upstream, at the confluence with the Vermillion River, the Wabash River has bankfull width and depth of 135 m and 5 m, respectively, and a mean annual discharge of ~227 m^{3}s^{-1} (*Konsoer and Rhoads, 2014*).

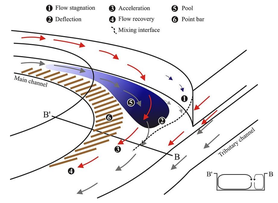
Confluences: *Hydro- and Morphodynamics*

Various research projects have been conducted at confluences along the Wabash River, focusing on the influence of momentum flux ratio, junction angle, and channel planform on flow structure, mixing, and morphologic change. Here, we choose to highlight key findings related to helical flow structure within confluent hydrodynamic zones of different planform configurations.

Low-angle confluent meander bend

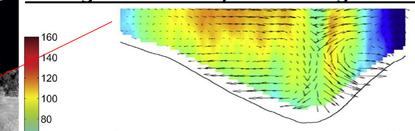


(left) Depth-averaged velocity vectors measured at Wabash River-Vermillion River confluence. (above) Cross-sectional flow fields showing structure of helical motion (*Konsoer and Rhoads, 2014*).

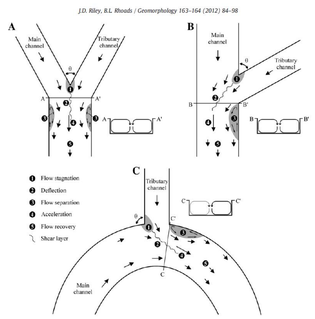


Conceptual model of flow structure and bed morphology at low-angle confluent meander bends (*Riley et al., 2015*)

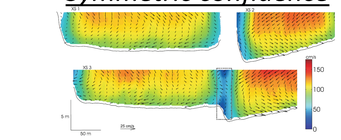
Straight tributary – curving main channel



(left) Depth-averaged velocity vectors measured at Wabash River-Embarras River confluence. (above) Cross-sectional flow field showing the presence of dual helical cells from converging flow streamwlines (*Rhoads and Johnson, 2018*).



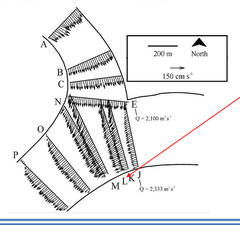
Symmetric confluence

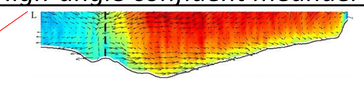


(left) Depth-averaged velocity vectors measured at Wabash River-White River confluence showing velocity deficit along shear layer. (above) Cross-sectional flow fields showing structure of helical motion (*Konsoer and Rhoads, 2014*).

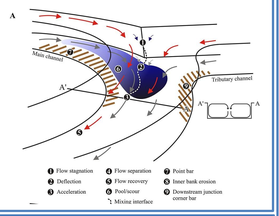
(above) Conceptual models of flow structure within the confluence hydrodynamic zone for various confluence configurations (*Riley and Rhoads, 2012*).

High-angle confluent meander bend



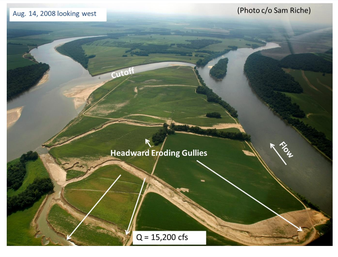


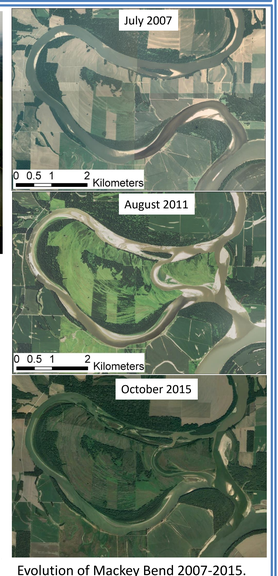
(left) Depth-averaged velocity vectors measured at Ohio River – Wabash River confluence (above) Cross-sectional flow field showing dual helical cells. (right) Conceptual model of flow structure and bed morphology at high-angle confluent meander bends (*Riley et al., 2015*).



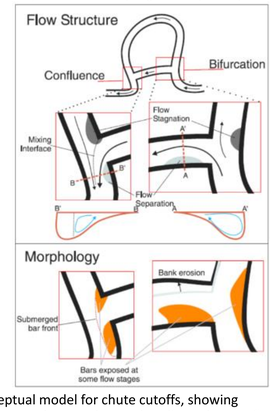
Cutoffs: *Sediment Flux/Channel Change*

- 1st chute cutoff develops in July 2008 over 8 days during flood event
- 2nd chute cutoff develops in June 2009, and becomes dominant flow path
- The two chute cutoffs mobilize large amounts of stored floodplain sediment (*Zinger et al., 2011*).

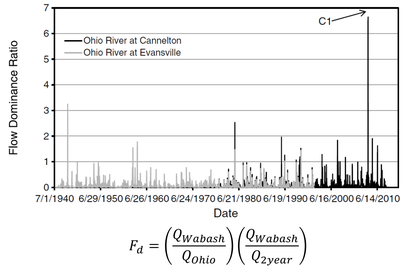




Evolution of Mackey Bend 2007-2015. Note presence and location of bars in 2011 and growth of vegetation in 2015.



Conceptual model for chute cutoffs, showing hydrodynamics associated with bifurcation-confluence, and expected depositional pattern of bars in zones of stagnation and recirculation. (*Zinger et al., 2013*).

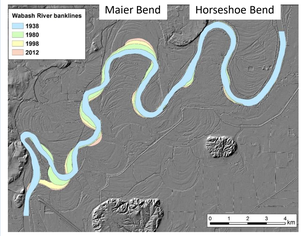


$$F_d = \left(\frac{Q_{Wabash}}{Q_{Ohio}}\right)\left(\frac{Q_{Wabash}}{Q_{2year}}\right)$$

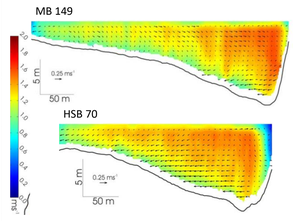
A factor shown to be important in the formation and evolution of Mackey Bend Cutoff is the influence of backwater effects from the confluence of the Ohio River, seen here through the *Flow Dominance Ratio*. (*Zinger et al., 2013*).

Curves: *Meander Bend Dynamics*

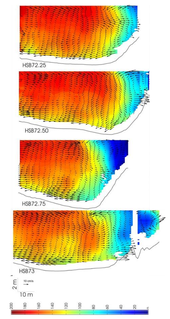
This research has sought to advance our understanding of complex interactions among flow structure, bed morphology, and planform geometry, how these interactions are affected by bank roughness and vegetation, and ultimately how rates and patterns of channel migration reflect these dynamic processes.



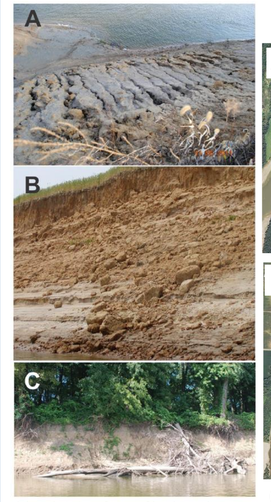
(above) Long-term planform evolution of Wabash River. (*Konsoer et al., 2016a*)



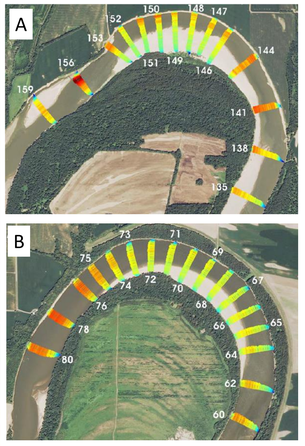
(above) Depth-averaged velocity vectors at apex cross sections for Maier Bend (top) and Horseshoe Bend (bottom). Note reduced velocities along outer bank of Horseshoe Bend. (*Konsoer et al., 2016b*)



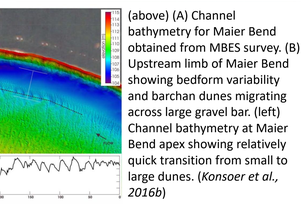
(above) Cross-sectional flow fields along Horseshoe Bend downstream of apex, spaced 40 m streamwise distance, showing influence of LWD on near-bank flow field. (*Konsoer et al., in prep)*

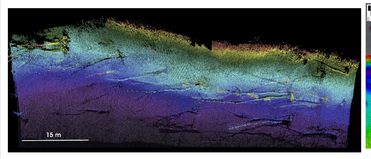


(above) Various forms of bank roughness. A&B) slump blocks and erosional rills along Maier Bend. C) large woody debris along Horseshoe Bend. (*Konsoer et al., 2017*)

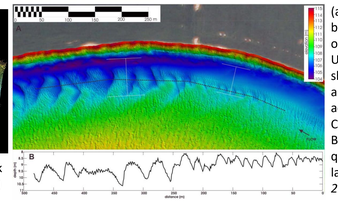


(above) Depth-averaged velocity vectors during a bankfull flood event for Maier Bend (A) and Horseshoe Bend (B). Note reduced velocities along outer bank of Horseshoe Bend. (*Konsoer et al., 2016b*)





(above) Submerged large woody debris (LWD) along outer bank of Horseshoe Run, mapped using MBES. (*Konsoer et al., 2016b*)



(above) (A) Channel bathymetry for Maier Bend obtained from MBES survey. (B) Upstream limb of Maier Bend showing bedform variability and barchan dunes migrating across large gravel bar. (left) Channel bathymetry at Maier Bend apex showing relatively quick transition from small to large dunes. (*Konsoer et al., 2016b*)

Future Research on Meandering Rivers

Bends
- Spatial variations in sediment transport rates and bedform geometry
- Interactions between flow and vegetation, influence on sediment transport and bank erosion in large rivers, incorporation into numerical models

Confluences
- Rates of mixing at large confluences
- Interactions between turbulent and mean flow and the influence of this interaction on changes in bed morphology

Cutoffs
- Upstream/downstream effects of cutoff on bed morphology and sediment transport
- Long-term effect of channel straightening on planform dynamics, incision vs increased sinuosity
- Patterns of bar and oxbow lake sedimentation, time scales of infilling, floodplain mass balance

[6] References

Please see additional handout for full list of publications, theses, and dissertations related to research on the Wabash River.

[7] Acknowledgements

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