Wabash River Modeling: Using River Meander Software to Predict Future Channel Migration

Justin Boldt, Hydrologist
U.S. Geological Survey
Indiana-Kentucky Water Science Center

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Study Objective:

What are the future potential impacts of the Wabash River on the I-64 bridge?
Outline

• Project Location & History
• Data Collection
• River Meander Model
Project Location
10 ft DEM from LIDAR
Project Location
Looking upstream at I-64 bridge
Significant Events

• **1985**: Upstream meander cutoff
• **1992**: Failure of RR pier
• **January 2005**: Significant flood event, failure of RR pier and collapse of attached trusses
• **May 2005**: DOT notified by commercial fisherman of significant increase in depth of water under I-64
• **July 2005**: Temporary scour countermeasures installed
• **2006**: Permanent scour countermeasures installed
1985: Upstream Meander Cutoff
Significant flood event in January 2005
Failure of RR pier on January 12, 2005
Wabash River at Mt. Carmel, IL

Top 5 Historical Crests

(1) 34.02 ft on 05/03/2011
(2) 33.95 ft on 01/13/2005
(3) 33.24 ft on 06/14/2008
(4) 33.00 ft on 03/30/1913
(5) 32.35 ft on 05/17/2002
Annual peak stage, in feet

USGS 03377500 - Wabash River at Mt. Carmel, IL

- Annual peak stage, in feet
- Water Year
- Major flood stage
- Moderate flood stage
- Flood stage (bankfull flow)
- Annual peak stage, in feet

Graph showing historical annual peak stages from 1880 to 2020.
USGS 03377500 - Wabash River at Mt. Carmel, IL

\[ y = 0.0592x - 92.195 \]

\[ R^2 = 0.1976 \]

USGS 03377500 - Wabash River at Mt. Carmel, IL

Annual peak stage, in feet

Water Year

y = -0.0025x + 26.173
R² = 0.0001

y = 0.1059x - 184.65
R² = 0.1567
DATA COLLECTION
XS #139

Elevation, in feet (NAVD88)

Distance from origin point on left bank, in feet

Feb 2013 bathymetry
Jan 2016 bathymetry

70 ft
Cutbank Erosion
Multibeam and Lidar data
May 2016

Courtesy: Rick Huizinga, USGS
RVR MEANDER MODEL
RVR Meander

• Simplified 2-D hydrodynamic and migration model
• Models the centerline migration of a meandering river
• Engineering time scales
• Two methods for computing centerline migration (bank retreat):
  – 1. “Classic” approach using a migration coefficient
  – 2. **Physically-based approach** that models the physical processes responsible for bank retreat (bank erosion)
Fluvial Erosion Rate

\[ E = \text{fluvial erosion rate} \]

\[ E = M \left( \frac{\tau}{\tau_c} - 1 \right) \]

\( M = \text{erosion-rate coefficient} \)
\( \tau = \text{shear stress acting on the bank} \)
\( \tau_c = \text{critical shear stress} \)
Physically-Based Approach

• Used 400+ cross sections throughout river reach.
  – $Q = 2,000 \text{ m}^3/\text{s}$ (bankfull discharge)
  – $W = 300 \text{ m}$
  – Channel slope = 0.00015

• Each cross section contains the physically-based parameters of the banks.
  – Critical shear stress
  – Erosion rate
  – Cohesion and other soil properties
Model Calibration

• Digitized the river centerline from 1998.
• Ran the physically-based method, adjusting parameters as needed, until the 1998 centerline migrated to the 2013 river centerline which was digitized from the DEM.
• The following plots show the RVR Meander model output for various sections of the river.
Model Calibration

- **Orange lines** = output from RVR Meander model
- 1 line/year for 15 years
- Model captures the migration from red line (1998) to blue line (2013)
Model Calibration

- Orange lines = output from RVR Meander model
- 1 line/year for 15 years
- Model captures the migration from red line (1998) to blue line (2013)
Research Questions

• Meander migration
  – Channel centerline 100 yrs into the future

• Increased peak flows (due to climate change or land use change)
  – How does meander migration change?

• Armoring along right bank just upstream of I-64 bridge
  – How does bank armoring affect meander patterns near bridge?
Future 100 years

Orange lines = output from RVR Meander model
Curvature Evaluation Tool
• **Blue line** = current (2013) centerline
• **Red section** = Bank armoring applied
• **Cyan lines** = output from RVR Meander model
• **1 line/year for 100 years**
Bank armoring vs. no bank armoring

- Blue line = current (2013) centerline
- Cyan lines = output from the model with bank armoring
- Orange lines = no bank armoring case
- 1 line /year for 100 years
- Model indicates that bank armoring keeps centerline from moving as far west and slows the migration south
Shear Stress, in lbf/ft²

I-64 bridge
RVR Meander model

• RVR Meander model was calibrated to historic centerlines
  – Good agreement of centerline migration from 1998 to 2013
  – Also predicts the migration at both the Grayville and New Harmony cutoffs
  – This provides confidence in the model

• Future scenarios show migrated centerlines 100 years into the future for:
  – Current conditions (base case)
  – Increased flows (bankfull + 10%)
  – Bank armoring on right bank upstream of I-64 bridge
RVR Meander model

• Model shows direction and magnitude of centerline movement for future scenarios
  – Impact on bridges, roads, and structures
  – Impact on land and utilities

• The model results provide information to make decisions about the I-64 bridge
  – Determining vulnerable locations
  – Assessing effect of bank armoring
  – Cost savings (scour protection, bridge realignment)
Conclusions

• *RVR Meander* model predicts future channel centerline migration

• Knowing where the river will likely migrate provides opportunity to mitigate damages caused by bank retreat before they occur
Questions?

Contact info:
Justin Boldt
U.S. Geological Survey
Indiana-Kentucky Water Science Center
jboldt@usgs.gov
502-493-1931 (office)
EXTRAS
Carved bathymetry in LIDAR
Carved bathymetry in LIDAR
Current centerline + 50 years

Migration coefficient method
Model Calibration: Grayville cutoff

- Orange lines are the output from RVR Meander model.
- Model captures the general migration from green line (pre-1900) to red line (1998) and the cutoff.
- The RVR Meander model was not created to model cutoffs, so what is commonly done is to identify likely cutoff locations when two migrated centerlines are within a half channel width (150 m) of each other.
FLOOD INUNDATION MAPS
Stage: 10.00 ft
Discharge: 32,500 cfs
Stage: 11.00 ft
Discharge: 36,700 cfs
Stage: 12.00 ft
Discharge: 40,900 cfs
Stage: 13.00 ft
Discharge: 45,200 cfs
Stage: 14.00 ft
Discharge: 49,600 cfs
Stage: 15.00 ft
Discharge: 54,000 cfs
Stage: 16.00 ft
Discharge: 58,400 cfs
Stage: 17.00 ft
Discharge: 62,900 cfs
Stage: 18.00 ft
Discharge: 67,400 cfs
Stage: 19.00 ft
Discharge: 72,000 cfs
Stage: 20.00 ft
Discharge: 78,000 cfs
Stage: 21.00 ft
Discharge: 84,000 cfs
Stage: 22.00 ft
Discharge: 91,400 cfs
Stage: 23.00 ft
Discharge: 99,000 cfs
Stage: 24.00 ft
Discharge: 108,000 cfs
Stage: 25.00 ft
Discharge: 118,000 cfs
Stage: 26.00 ft
Discharge: 129,000 cfs
Stage: 27.00 ft
Discharge: 142,000 cfs
Stage: 28.00 ft
Discharge: 158,000 cfs
Stage: 29.00 ft
Discharge: 174,000 cfs
Stage: 30.00 ft
Discharge: 192,000 cfs
Stage: 31.00 ft
Discharge: 210,000 cfs
Stage: 32.00 ft
Discharge: 230,000 cfs
Stage: 33.00 ft
Discharge: 250,000 cfs
Stage: 34.00 ft
Discharge: 270,000 cfs
Stage: 35.00 ft
Discharge: 290,000 cfs
Stage: 35.59 ft
Discharge: 306,300 cfs
Stage: 35.59 ft
Discharge: 306,300 cfs

Grayville

New Harmony