Advancements in Two-Dimensional Floodplain Modeling with SRH-2D / SMS

WHAT is CHANGE?

Collaborative

Hydraulics:

Advancing to the

Next

Generation of

Engineering

Image Source: FHWA
Why are we concerned about bridge hydraulics?

614,387 Bridges
509,358 over water
Hydraulic Modeling
The Past – Where did it all begin?

• Prior to 1957 Bridges were not hydraulically designed
• 1960 FHWA released HDS-1 – basic analysis approach
• 1966 US Army COE released HEC-2 – first water surface profile model (1D modeling)
• 1988 First use of 2D modeling by FHWA (FESWMS)
• 1996 US Army COE released HEC-RAS (1D)
• 2012 FHWA officially started recommending 2D modeling for complex bridge hydraulics
The Past/Present – 1D Modeling Assumptions

- Cross section / flow direction
- Channel roughness values continuous between sections
- Average reach lengths
- Ineffective flow areas
- Contraction/expansion coefficients
- Constant water surface elevation
- Average velocity across section
- Overbank continuity not preserved

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)
The Past – 1D Modeling

“The more I learn, the more I realize how much I don’t know.”

- Albert Einstein

Image Source: Creative Commons Zero – CC0
The Past – Consequences of 1D Modeling Assumptions

Image Source: Nebraska Department of Roads
What has changed?

- Greater availability of mapping data
- More computer power
- Improved 2D computer models
- Enhanced graphical interface
- More compatibility with CAD and GIS

Image Source: FHWA
The Present – 2D Modeling Tools for Complex Hydraulics

- FHWA/USBR partnership (2013)
- SRH-2D two-dimensional hydraulic model
  - *Developed by Dr. Yong Lai (USBR)*
- Incorporated hydraulic structures
- Custom graphical user interface in SMS
  - *Developed by Aquaveo*
- Ongoing development for transportation hydraulics
- Free community version

Image Source: FHWA
The Present – 2D Modeling

- Cross section / flow direction
- Manning’s n values continuous between sections
- Average reach lengths
- Ineffective flow areas
- Contraction/expansion coefficients
- Constant water surface elevation
- Average velocity across section
- Flow distribution based on available conveyance

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)
The Present – 2D Modeling Benefits

- Flow direction is computed
- Multiple flow paths represented
- Velocity distribution is computed
- Water surface and velocity computed at each element
- Graphical visualizations help to communicate results
- Additional analysis tools are available

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)
The Present – 2D Modeling Graphical Visualizations
The Present - Modeling Capabilities

Pressure Flow

Piers

Buildings

2D Culverts

HY-8 Culverts

Internal Boundary Conditions

Image Sources: USGS / Earthstar Graphics (Aerial Image) – Mississippi DOT / FHWA
Present - Modeling Capabilities

Additional Features / Capabilities
- Multiple boundary conditions
- Internal source/sink
- Steady and unsteady flow
- Sub- and supercritical flow
- Normal/critical depth rating curves
- Bridge piers and blocked obstructions
- Gates
- Weirs
- Depth dependent roughness
- Sediment Transport

Image Sources: USGS / Earthstar Graphics (Aerial Image) – Mississippi DOT
Present – 2D Modeling Applications
Multiple Structures

Image Sources: New Hampshire DOT / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications
Floodplain Mapping and Risk Assessment
Present – 2D Modeling Applications
Flooding Impact Assessment

Image Sources: Montana DOT / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications
Undefined flow paths
Present - 2D Modeling Applications
Streamlined Bank Protection Design – Data Calculator

HEC-23 v2 Eq 4.1

\[ d_{30} = y(S_f C_s C_v C_T \frac{(V_{des})}{\sqrt{K_1(S_g - 1)g_y}}} \]

Image Sources: FHWA/CDOT / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications
Flow around bends

Image Sources: CDOT / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications

Instream Structures
Present – 2D Modeling Applications
Skewed Bridges

Image Sources: Montana DOT / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications
Comparison with 1D Model Results – Summary Tables
Present – 2D Modeling Applications
Habitat Analysis

Salmon spawning nest (redd) locations vs. channel shear stress

Fish passage analysis using flow depth and velocity distribution
Present – 2D Modeling Applications

Dam Break Analysis

Image Sources: Aquaveo / Earthstar Graphics (Aerial Image)
Present – 2D Modeling Applications
Tidal Boundary Conditions
Present – 2D Modeling Applications
Bridge Scour Assessment

Summary Table

<table>
<thead>
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<th>Reach</th>
<th>Station</th>
<th>Flow</th>
<th>Width</th>
<th>Depth (ft)</th>
<th>Unit Discharge (cfs-ft)</th>
<th>Velocity (fps)</th>
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Image Sources: Alaska DOT/WFL / Earthstar Graphics (Aerial Image)
The Future – Where are we going?
The (near) Future – 2D Modeling Applications

Bridge Scour Assessment Tools

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<th>Parameter</th>
<th>Value</th>
<th>Units</th>
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Image Sources: FHWA / Earthstar Graphics (Aerial Image)
The Future – 2D Modeling Applications
Bridge Scour Assessment Tools
The (near) Future
2D Floodway Delineation

Image Sources: Colorado DOT / FHWA / Earthstar Graphics (Aerial Image)
Resources

START HERE
https://www.fhwa.dot.gov/engineering/hydraulics/ (Search FHWA Hydraulics)

SOFTWARE
• Licensing (DOTs, Community License, Reviewer’s license)
• Tutorials
• Online User’s Guide

TRAINING
• NHI 2D hydraulic modeling course
• Advanced NHI 2D hydraulic modeling online training
• YouTube video tutorials (Search FHWA SRH-2D July 2017)
• 2D Hydraulic Modeling User’s Forum webinars (email Scott Hogan)

TECHNICAL SUPPORT
• FHWA Resource Center (DOT/FHWA) and Aquaveo
Questions?

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