The Coming Flood of 2D Models

Mitch Blum, HDR Engineering Inc.
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Outline

- 1D Modeling vs. 2D Modeling
- HEC-RAS 5
- Traditional Barriers to 2D modeling
- “Flood” of 2D Models
- Regulatory Implications
1D vs 2D Modeling
1D Modeling

- Steady State
- Unsteady State
- Cross Sections in ONE Direction
- Hydraulic Computations in ONE Direction
- Step Backwater
  - Solves one direction
  - Downstream to upstream
1D Modeling

Advantages
- Simple cross sectional geometry
- Simple to run
- Faster computation time
- Hydraulic Structures
- Lots of supporting literature

Disadvantages
- Trouble modeling shallow overland flows
- Can overestimate depth and velocity due to 1D assumptions
- Laying out cross sections difficult
- Requires engineering judgment
- Doesn’t capture complex dispersive flow

Continuity Equation:
\[ \frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \]  
(Only in X direction)

Momentum Equation:
\[ \frac{\partial Q}{\partial t} + \frac{\partial (\alpha Q^2/A)}{\partial x} + gA \left( \frac{\partial h}{\partial x} - S_o + S_f \right) = 0 \]
2D Modeling

- Uniform Grid – Square cells
- Rectilinear Grid – Rectangular cells
- Unstructured Grid/Mesh
  - Triangles
  - Quadrilaterals
  - Polygons
- Unsteady-state
- Hydrodynamics in 2 directions
- Shallow water equations
2D Modeling

- **Advantages**
  - Simple overland model construction
  - Dispersive shallow flow
  - No guessing at cross section orientations
  - More informative dynamic mapping
  - Modeling in 2 directions

- **Disadvantages**
  - More data intensive to build
  - Limited on hydraulic structures
  - Heavy reliance on terrain quality
  - Computational time and power
  - Expensive (commercial)
1D Tanana Model

- Complex Unknown Flow
- 50 Lateral Structures
- 3 Reaches
- Stability Issues
Urban Hydrodynamics
Is 2 Always Better Than 1?

When is a 1D Model Appropriate

- Flow contained in banks
- Well defined floodplain
- Well defined flow path
- Constant WSEL can be assumed across section
- For RAS when bridges under pressure flow
- Modifying or duplicating effective models
Need for 2D Modeling
Extreme Events Driving Analysis, Policy and Regulation

“Post Katrina World”

- Katrina
  - Post Katrina Emergency Management Reform Act 2006
  - Tighter Regulations
  - More emphasis on analysis
Extreme Events Driving Analysis, Policy and Regulation

- Dam Breach
  - Statewide Requirements
  - Emergency Management Plans
  - Typically Urban for High Hazard
- Levee Breach
  - Urban Settings
- Early Warning Systems
  - Mississippi USACE Breach
Mississippi Ohio River Flooding 2011

- Forced Levee Breach
- Installed over 100 Temporary Gages to Capture the Event
- Used as Model Validation

Source: HEC
HEC-RAS 5

- 1D/2D Integrated Hydrodynamic Model
- Regular or Irregular 2D Grid Cells
- Finite Volume Solution
- Full Saint Venant or Diffusion Wave Equation Solution Options
- Unstructured or Structured Computational Meshes
- Detailed Hydraulic Table Properties for Computational Cells and Cell Faces
- RAS Mapper
How is it Different?

- Public Domain
- Extensively Tested
- Computationally Efficient
- Terrain Processing
- New Codes
  - Not repackaging existing codes
- Unique Approach to 2D Solution
  - Sub grid cell terrain detail
- Integrated Mapping
RAS Mapper

- Terrain Creation and Association
- Multiple Terrain Support
  - Hierarchical control
- Flexible Tile – Resolutions
- Less terrain file size limits
- Map Projection
  - Reference or manual assign
- Shapefile backgrounds
- Web Imagery
HEC-RAS Visualization

- Static and Dynamic Results
  - Depth
  - Water Surface Elevation
  - Velocity
  - Inundation Boundary
  - Flow
  - Depth * Velocity
  - Arrival Time
  - Recession
  - Duration
  - Percent Time Inundated

- Web Imagery
- Shapefiles
- Profiles
Visualization
The “Flood” of 2D Models
Historic Impediments to the “Flood” of 2D models

- Cost
- Computational Power
- Reliance on GIS or CAD systems
- FEMA Acceptability
- Regulatory Modeling Guidelines
Breaking Down the Barriers of 2D Modeling
Cost

- HEC-RAS 5.0
  - Free to download, install, and use
  - Upwardly compatible
  - Free documentation
  - Ongoing support
- Proprietary Software
  - Upward of $60,000
Advances in Computer Hardware and Software

- 64 Bit Computations
- Multiple Processors
- Faster Processors
- Solid State Memory
- Video Graphic Cards
- Shorter Runtimes
- Larger Storage Available for Output
Reliance on GIS or CAD

- HEC-RAS Moving Away from GIS
- Geospatial Processing within HEC-RAS
  - Pre-processing Model geometry
  - Terrain development and modification
  - Modeling output and visualization
Regulatory Implications
Emergency Action Plan Support

- **State Requirement**
  - High Hazard
  - Significant Hazard

- **Emergency Action Planning**
  - State Law Requires EAP
  - 27,168 High and Significant Hazard Dams*
    - Nationally
  - 8,110 Dams without EAP*

- **Dam Breach**
  - Dam breach parameterization and analysis
  - Advanced hydraulics for urban setting

*US Army Corps of Engineers National Inventory of Dams 2013
FEMA Regulations and Guidance

- National Flood Insurance Program 1968
  - Regulations reflect technical capabilities at the time
  - Based upon regulatory framework in the 1970’s
- 44 CFR 60-65
  - Written when steady state 1D models were state of the art
  - Mapping entire country on limited budget
- Guidelines and Specifications
  - Limited 2D Guidance
  - Mapping standards are not set-up for complex modeling
## Current FEMA Accepted 2D Models

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>DEVELOPED BY</th>
<th>AVAILABLE FROM</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>v. 1.1 and up (Jun. 1995)</td>
<td></td>
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<tr>
<td>FLO-2D</td>
<td>Jimmy S. O'Brien</td>
<td>FLO-2D Software, Inc. P.O. Box 66 Nutrioso, AZ 85932 FLO-2d.com/</td>
<td>Hydrodynamic model that has the capabilities of modeling unconfined flows, complex channels, sediment transport, and mud and debris flows.</td>
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<tr>
<td>v. 2007.06 and 2009.06</td>
<td></td>
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<tr>
<td>MIKE Flood HD</td>
<td>DHI Water and Environment</td>
<td>DHI, Inc. 319 SW Washington St. Suite 614 Portland, OR 97204</td>
<td>A coupling of MIKE 11 (one-dimensional) and MIKE 21 (two-dimensional) models. Solves the fully dynamic equations of motion for one- and two-dimensional flow in open channels, riverine flood plains, alluvial fans and in costal zones.</td>
</tr>
<tr>
<td>v. 2009 SP4</td>
<td></td>
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<tr>
<td>TABS RMA2</td>
<td>US Army Corps of Engineers (USACE)</td>
<td>Coastal Engineering Research Center Department of the Army Waterways Experiment Station Corps of Engineers 3909 Halls Ferry Road Vicksburg, MS 39180-6199</td>
<td>Limitations on split flows. Floodway concept formulation unavailable. More review anticipated for treatment of structures.</td>
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<td>v. 4.3 and up (Oct. 1996)</td>
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<td>RMA4</td>
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<td>v. 4.5 and up (July 2000)</td>
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<tr>
<td>XP-SWMM 2D/XPStorm 2D</td>
<td>XP Solutions</td>
<td>XP Solutions 5415 SW Westgate Dr. Suite 150 Portland, OR 97221 XPSolutions.com</td>
<td>Simulates two-dimensional free surface flows by solving the full-dimensional, depth averaged, momentum and continuity equations. Dynamically linked with the one-dimensional modeling of XP-SWMM/XP-Storm.</td>
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<td>v. 12.00 (May 2010)</td>
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Regulatory Implications

- Approved FEMA Model List
  - HEC-RAS automatically approved upon release
  - Extensive validation process

- Applicability of Use
  - Justification to FEMA to use 2D
  - Is the Effective Model adequate?

- Floodway Challenges
  - Method 4 not available
  - Method 1 not available
  - Use of terrain to block encroachments

- Model Review
  - Challenge to find experienced reviewers
2D Model “Flood” Preparedness

- **Education**
  - Understanding how the model works
  - Training staff
  - “How to Review a 2D Model”

- **Anticipate and Plan**
  - What communities are appropriate for 2D?
  - Emergency response needs

- **Reach out to others**
  - Communities
  - Experts
  - Regulators