2D Model Implementation for Complex Floodplain Studies

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2D Case Studies

• Case Study 1

*Rain-on-Grid* 2D floodplain simulation for unconfined flat topography in coastal plain areas of Georgia

• Case Study 2

*1D/2D Integrated* floodplain modeling for complex flooding in Texas
2D Case Studies

• Case Study 3
  2D floodplain modeling for dam/levee breach analysis

• Case Study 4
  Embankment Opening to increase conveyance and improve circulation

• Case Study 5
  2D Modeling of wash area
Flat Coastal Plain Floodplain Modeling

- GA coastal communities have inland areas of very flat terrain
  - Flow travels in many directions
  - Frequent divergence/convergence and break out of flows
  - Interconnected and closed basin ponds and swamps

- Very challenging for a 1D model
  - User cannot confidently estimate flow direction in 1D
  - Flow divergence and convergence requires many river reaches and is not efficient to model
Effective Zone A Floodplains

- No supporting engineering data or even documentation of methodologies used
- Appear to be developed using:
  - Soil data
  - USGS topography
- Very simple floodplain boundaries
- Poor match to new LiDAR data
What is Rain of Grid Hydrology?

- Applying rainfall directly to 2D grid cells
- Let xp2D figure out where the rain drops flow and accumulate!
  - No need to delineate watershed boundaries
  - Infiltration losses accounted for each grid cell
  - Very rapid to create

Validation of Rain on Grid

• New technology, relatively untested

• Limited research in area

• Must perform a thorough testing and calibration of parameters to ensure results are valid
  • Plotted regional curves by analyzing available USGS gages in coastal plain region

• Effectiveness of rain on grid will vary in different hydrologic conditions – Generally more effective in flat areas
Coastal Georgia Regional Stream Gage Analysis:

Drainage Area vs. Peak Flow

Using 29 USGS Gages in 12-County Area

- Bulletin 17B
- XPSWMM Output
- Power (Bulletin 17B)
- Power (-66.7 C.L.)
- Power (+66.7 C.L.)
- Power (+95% C.L.)
- Power (-95% C.L.)
- Linear (Trib4)
Scalable Solution

• xp2D provided a very scalable solution
  • Basic level of analysis purely 2D grid based
  • Can enhance detail by adding 1D features
    • 1D culvert features are generally required to hydro-enforce embankments
    • 1D channel features can help improve hydrology where channels provide significant conveyance, more critical in areas of steeper terrain
  • Grid cell requires different thinking
    • Minor differences in results between 100 ft and 200 ft cell sizes was experienced
1. Basic floodplain from 2D only model

2. Refinement of model with 1D links for cross drains

3. Rerun refined model which reduces upstream flooding and increases downstream flooding
Refined Zone A Floodplain Delineations
Refined Zone A Floodplain Delineations
xp2D in Flat Topography Summary

• Benefits of the xp2D model
  • Very fast to develop basic floodplain for very large area (several hundred square miles)
  • Straight forward to integrate 1D features and refine 2D model, much easier than many other 2D models
  • Rain-on-Grid method can identify comprehensive floodplains within a study boundary, not just scoped reaches

• Recommendations
  • Smaller isn’t better when it comes to selecting 2D grid cells
  • Recommend delineating floodplain within GIS at a finer resolution since every cell has a flood elevation
xp2D in Flat Topography Summary

• Challenges
  • Simulations for large area take a long time
  • Model grid too coarse for final Floodplain Boundary
    Standard compliant flood hazard area
  • Rain on grid model creates floodplain for 100% of cells
  • Must determine threshold to define a flood

• Solutions
  • Tested 2D cell size sensitivity and optimized for efficiency
  • Screen final results to only include cells with depth >1 foot
  • Redelineate using finer mesh terrain (10 foot)
  • Being pilot tested for First-Pass analysis to aid
discovery and Risk Assessment
Complex Hydraulics in Texas

- Highly altered flooding source containing:
  - Excavated flood relief channel parallel to and below a perched main channel
  - Converging flooding sources
  - Multiple openings through major road embankments
  - Major grading activities have occurred influencing flow direction

- Very challenging to develop a 1D model

- Integrated 1D-2D model provided a solution for modeling complex conditions
Integrated 1D/2D Model

1D-2D interface allows flow exchange between 1D/2D engines by balancing energy grade.

Overbank areas modeled as 2D grid.

Well defined channels modeled in 1D.

Hydraulic structures modeled in 1D.
Results Highlight Need for 2D
Parallel HEC-RAS Model

• Traditional 1D models are generally more readily accepted for FEMA studies
  • xp2D model enabled HEC-RAS geometry setup to be confidently determined
  • xp2D grid elevations could be contoured to determine RAS cross section alignments
  • Areas of negligible energy slope can be modeled in RAS as storage nodes

• Calibration and comparison of results
  • HEC-RAS generally gave a little higher results
  • Hard to model in just 1D where elevations suddenly change laterally (break outs)
xp2D for Complex Hydraulics

• Benefits of the Integrated xp1D/2D model
  • Straight forward to integrate 1D features and refine 2D model, much easier than many other 2D models
  • SWMM Link-Node method is very versatile, enabling complex hydraulic structures to be effectively modeled
  • Good stability, relatively low effort required to stabilize model compared to other dynamic models on the market
  • Excellent continuity (generally easier than just 1D model)

• Recommendations
  • Develop 1D model incrementally to help diagnose stability issues
  • Choose suitable mesh resolution to optimize run times
2D Dam/Levee Breach Modeling

- Above ground pumped storage reservoir
  - Ring levee, not a traditional dam across a valley
  - More places for the dam to breach
  - Major residential areas on one side of dam

- Unconfined flooding making 1D model challenging

- FLO-2D model provided solution to route breach wave from multiple breach locations
Sensitivity of Breach Location

This map represents the depths of flooding that would occur in the unlikely event of a failure to the north embankment of the proposed Upland Storage Reservoir during normal full pool (high water level) conditions. Since there are no penetrations (pipes) through the northern embankment, this embankment has a reduced risk of failure.
Arrival Times

This map represents the approximate arrival times of flooding in the unlikely event of a failure to the north embankment of the proposed Upland Storage Reservoir during normal full pool (high water level) conditions. Since there are no penetrations (pipes) through the northern embankment, this embankment has a reduced risk of failure.
2D Dam/Levee Breach Modeling

• Benefits of the FLO-2D model
  • Enabled overland flow to be modeled including inertia which would have been ignored by a basic 1D model that would have funneled all flow through channel
  • Enabled the risk sensitivity of the breach location to be clearly understood
Embarkment Opening to Increase Conveyance and Improve Circulation

• Using 2D models to identify hydraulic effects of opening up sections of roadway embankment
  • Restores the natural function and flow of floodplain
  • 2D model demonstrates how it is not a 1D problem
2D Modeling
2D Modeling Over Alluvial Wash
2D Levee Breach
Questions?

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