Leveraging Advances in 2D Modeling for Infrastructure Risk Assessments

18th ACEC-SC/SCDOT Annual Meeting

December 2, 2015

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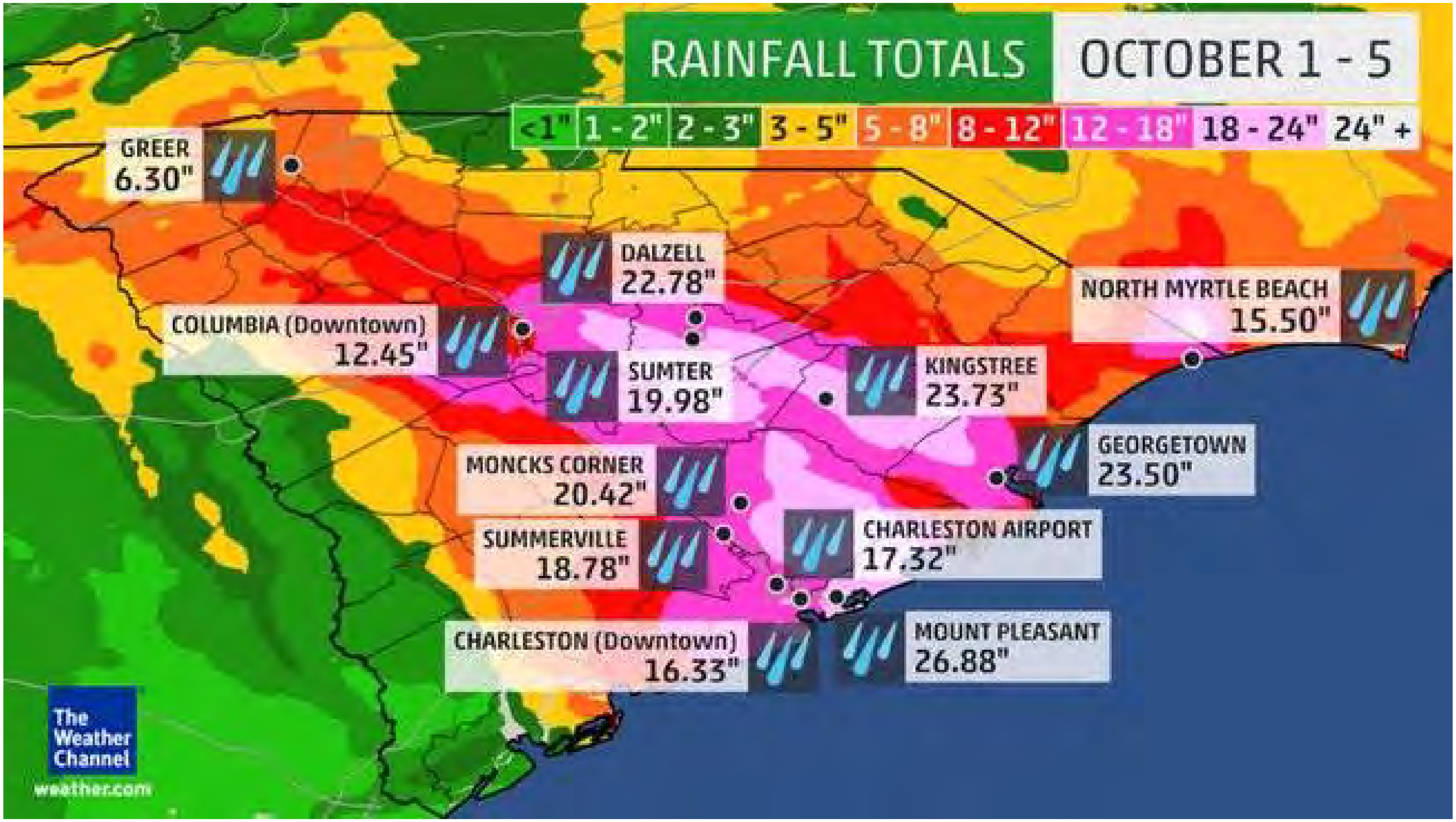
What We Will Cover

- October 2015 Flood Impacts
- What is Flood Risk?
- What are the benefits of 2D modeling
- Advances in 2D Modeling

Floods of October 2015



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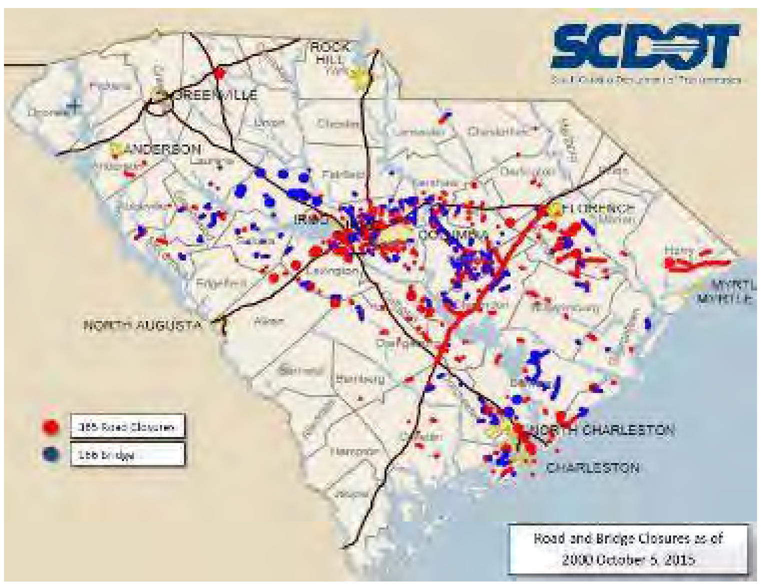
Widespread infrastructure damage

- 700+ roads and bridges closed
- 30+ dams failed
- Widespread utility damages



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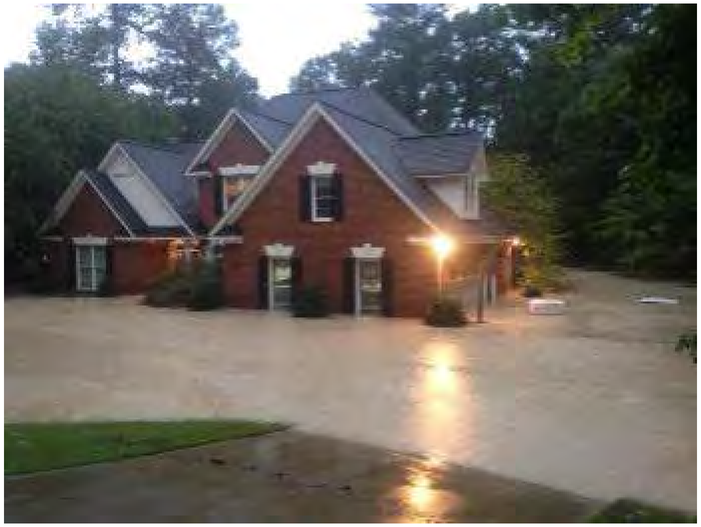
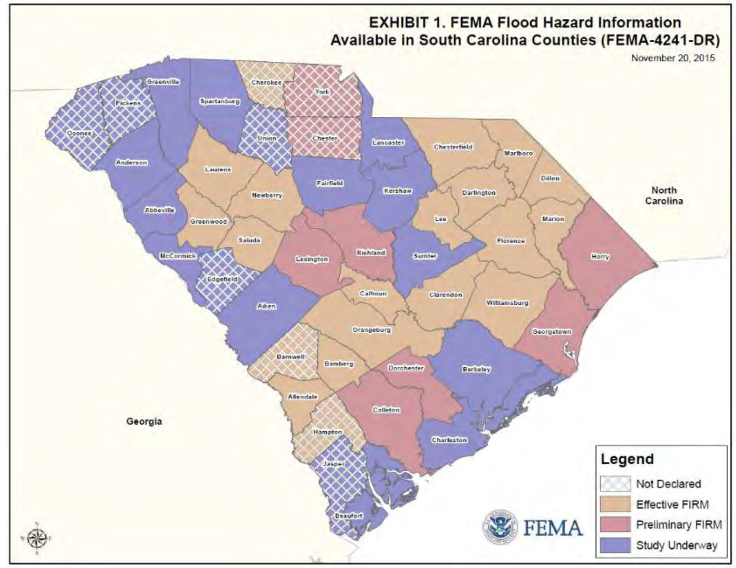
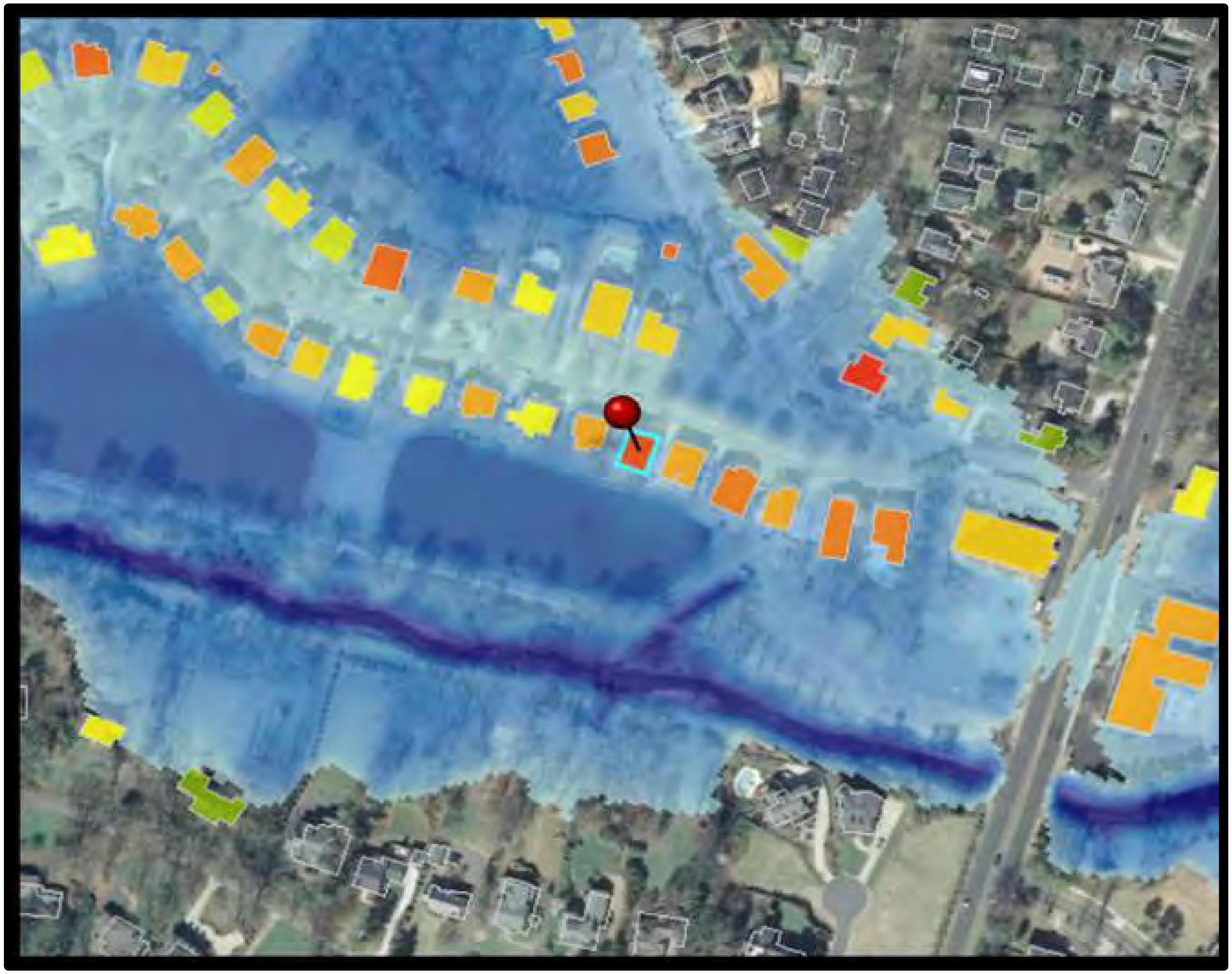
$1 Billion + in damage





- 150,000+ homes impacted
- 19 lives lost
- 36 counties declared for disaster assistance

Improving Resilience Through Enhanced Flood Risk Management



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Defining Flood Risk

Hazard ≠ Risk

Risk = likelihood x consequences

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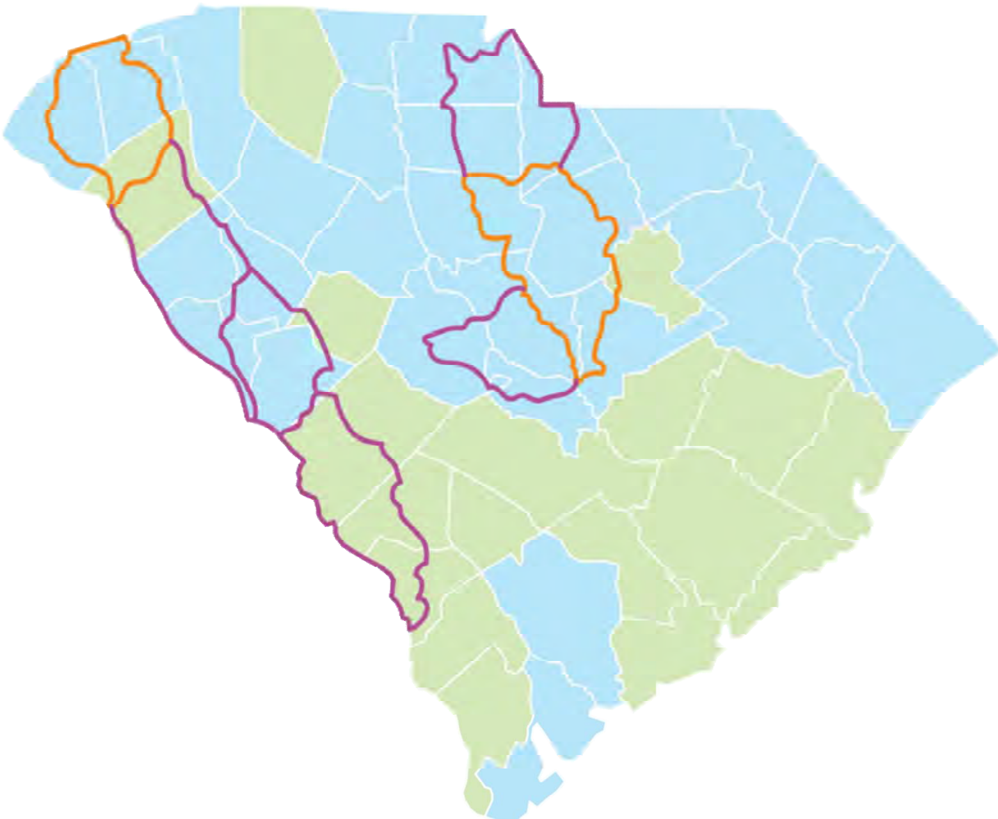
Flood Hazard Mapping in South Carolina since 2000



Since 2000 SCDNR Has Produced

– 53 studies

– 12,000 miles of H&H

– 200 miles of coastal

– 3,700 FIRM panels

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History of 2D Modeling – In the Beginning

2D modelling first used in Coastal Modelling

- flows assumed to be depth averaged
- large areas of wetting and drying
  - o long lengths of beach and
  - o large study areas with different boundaries conditions
- no flow control structures
- readily available topographic data from admiralty
- Used by industry to model sediment and pollutants
- Time consuming to run and needed powerful computers

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History of 2D modelling – early 2000's

- LiDAR ground data became readily available
- Modelling standards and methodologies developed
- 2D coastal software adapted to model overland flow
- development of linking 1D and 2D
- desktop computers had increased computing power

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History of 2D modelling – Today

Today

- Fully integrated 1D/2D hydraulic packages with GIS capability built in
- Large volumes of spatial data available cheaply
- **Can include direct rainfall**
- **Computers capable of modelling large amount of data (GPU and CPU)**
- Expectations of modelling are far greater
- Inclusion of storm sewer and drainage systems

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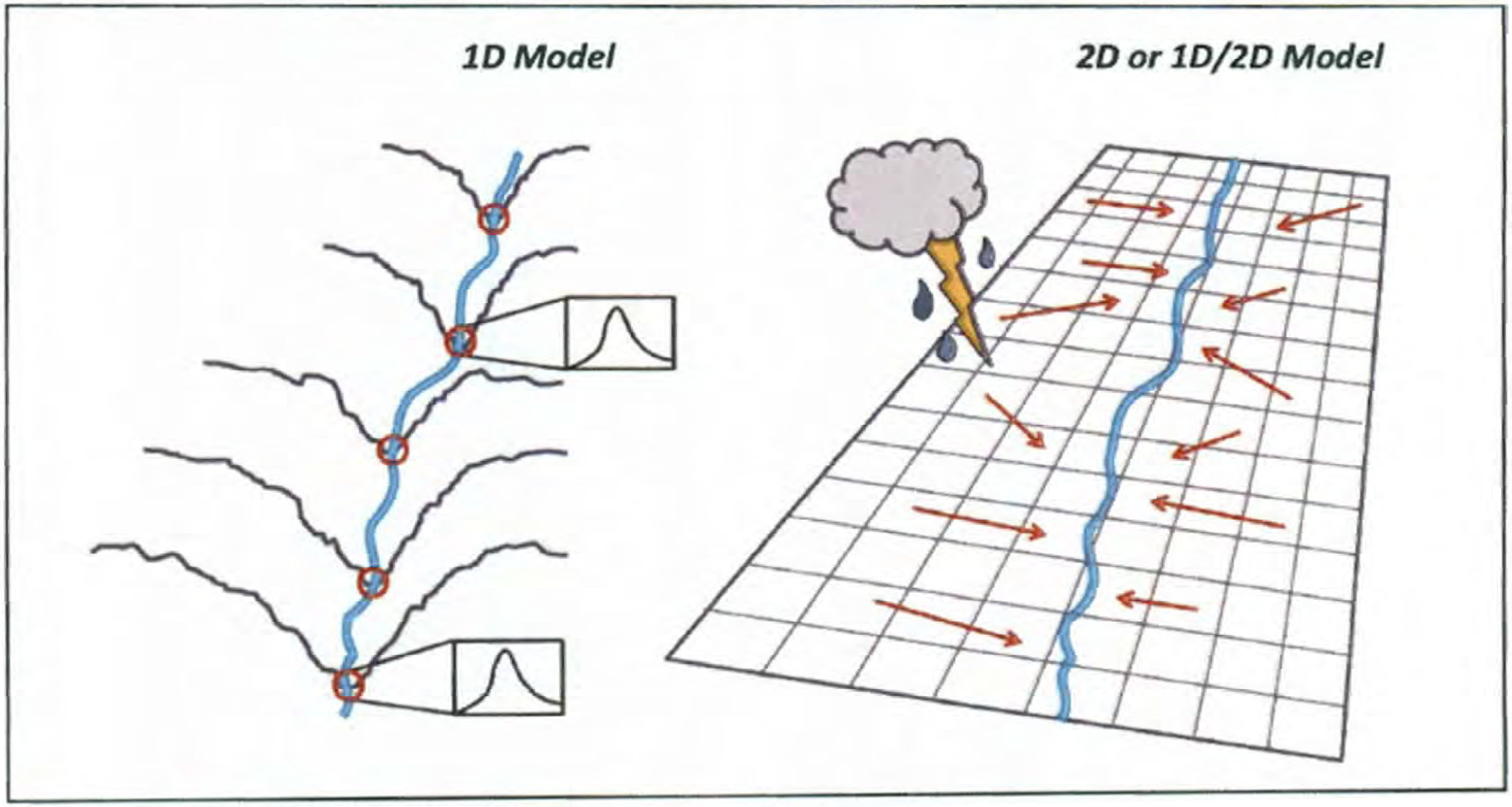
1D vs 2D Modelling



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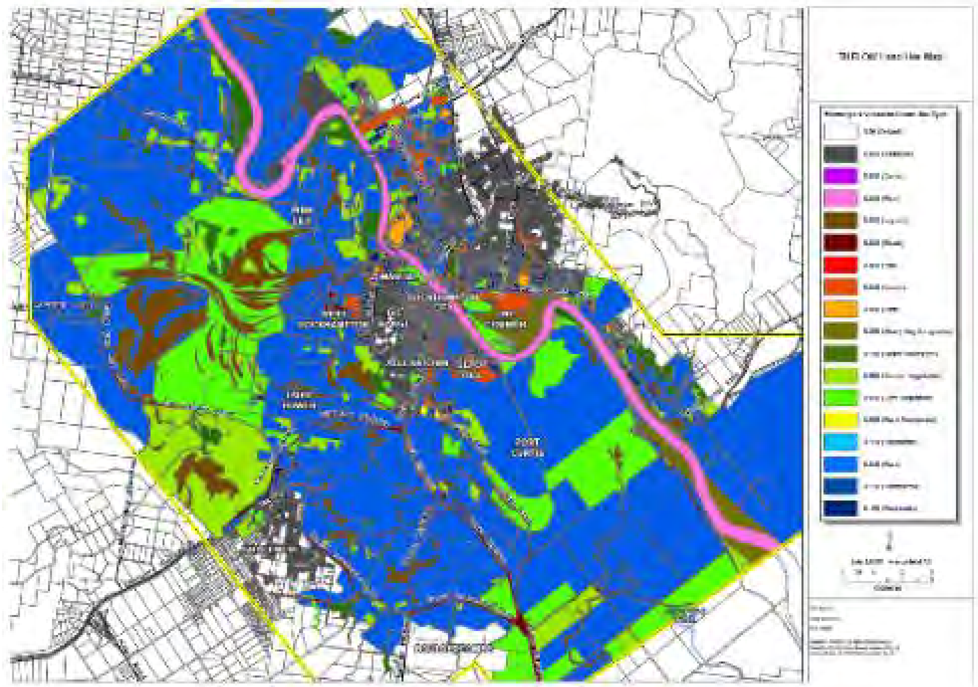
Land use (roughness map)

- **Roughness is representative of land use**
- **Usually Manning's "n"**
- **Can be either a grid or polygons (depending on model)**



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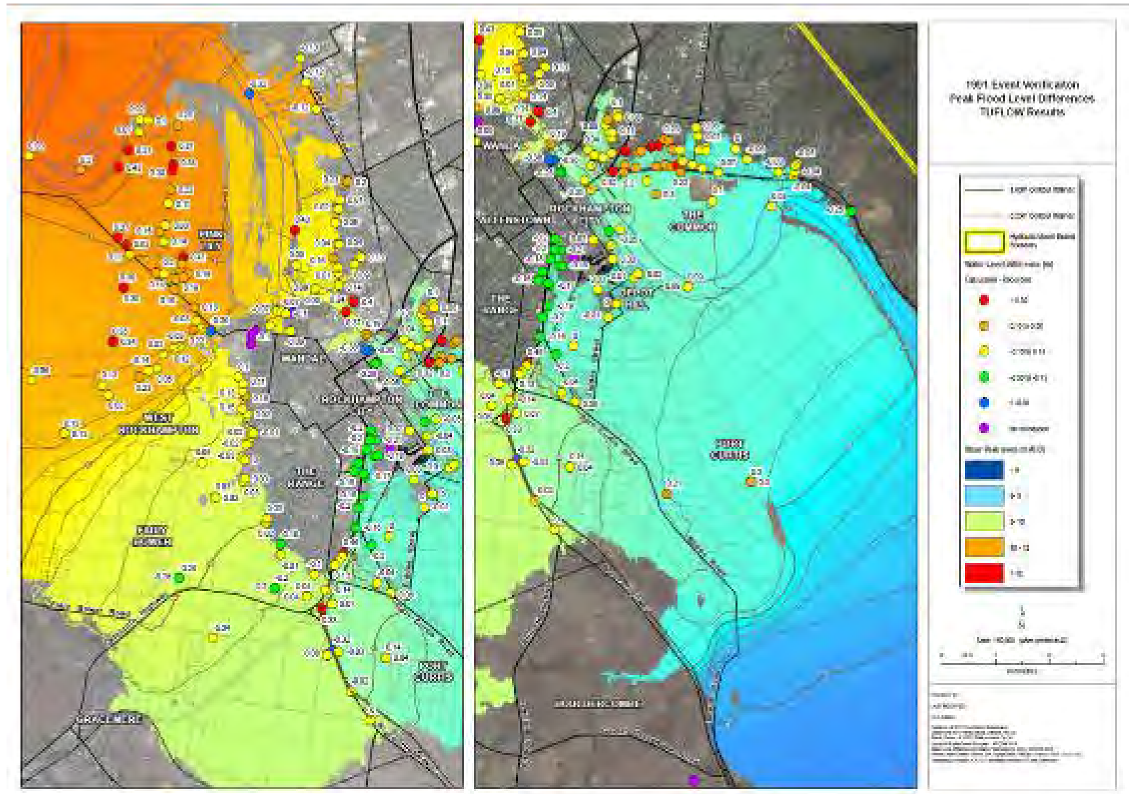
Model calibration

- **Graphical representation of the model calibration is straight forward**
- **Model outputs are in GIS format and figures can be produced easily**



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Urban system

- **Combined 1D-2D models can represent:**
  - **Overland flow (2D)**
  - **Creeks (1D open channel)**
  - **Pipes (1D closed conduit)**
  - **Pumps and other hydraulic controls**

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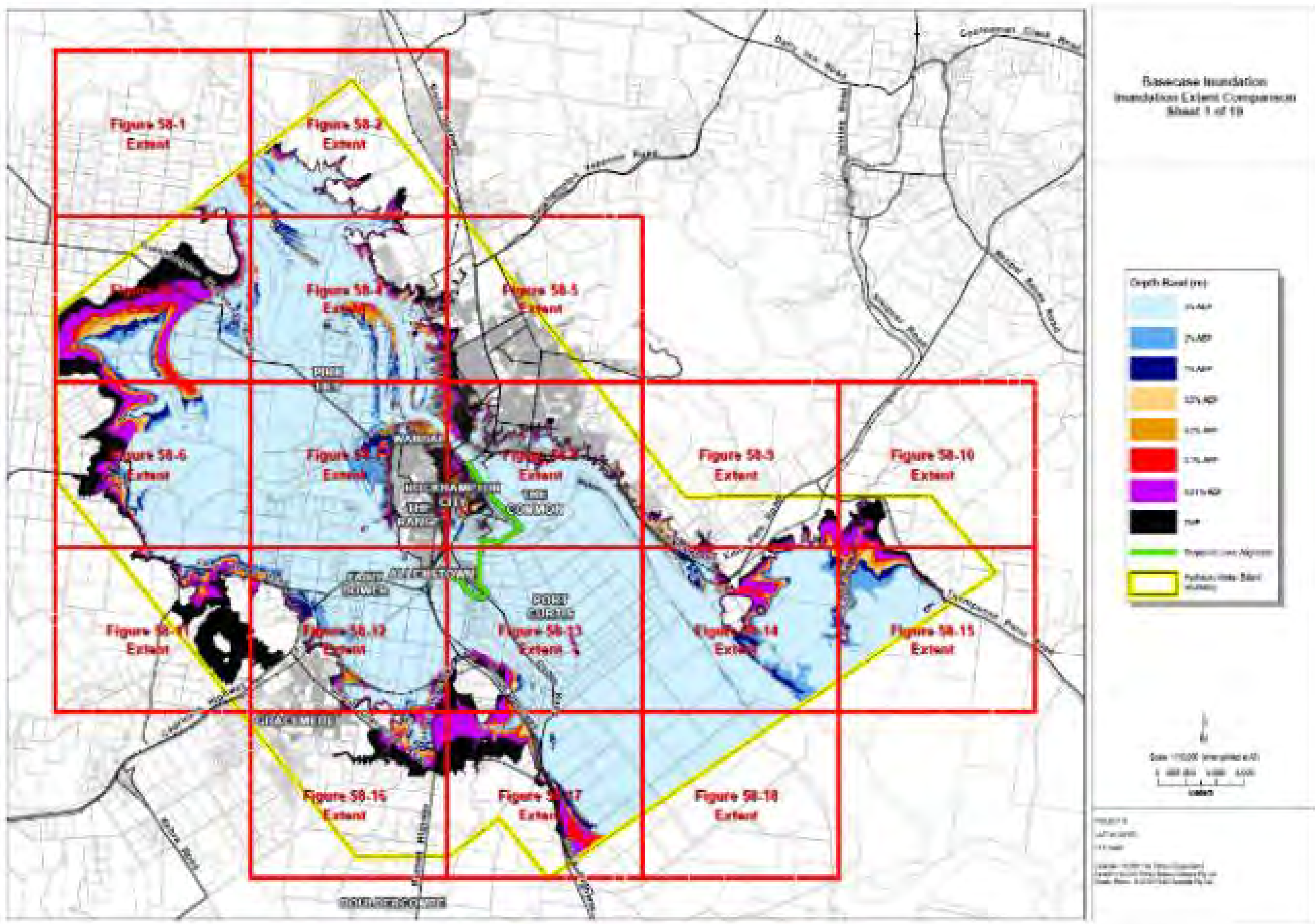
Outputs - Inundation extents



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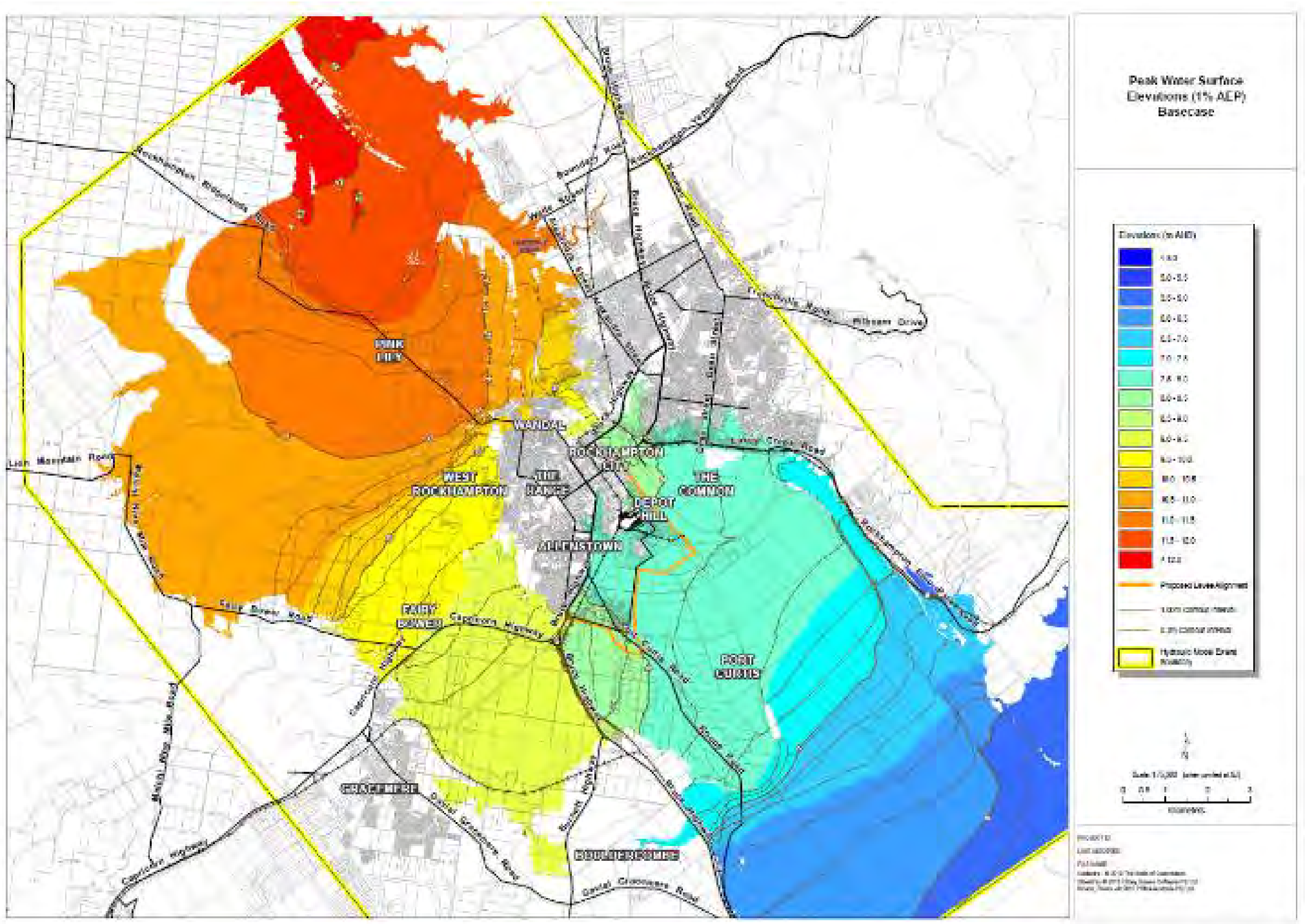
Peak Water Surface Elevation (1% AEP)



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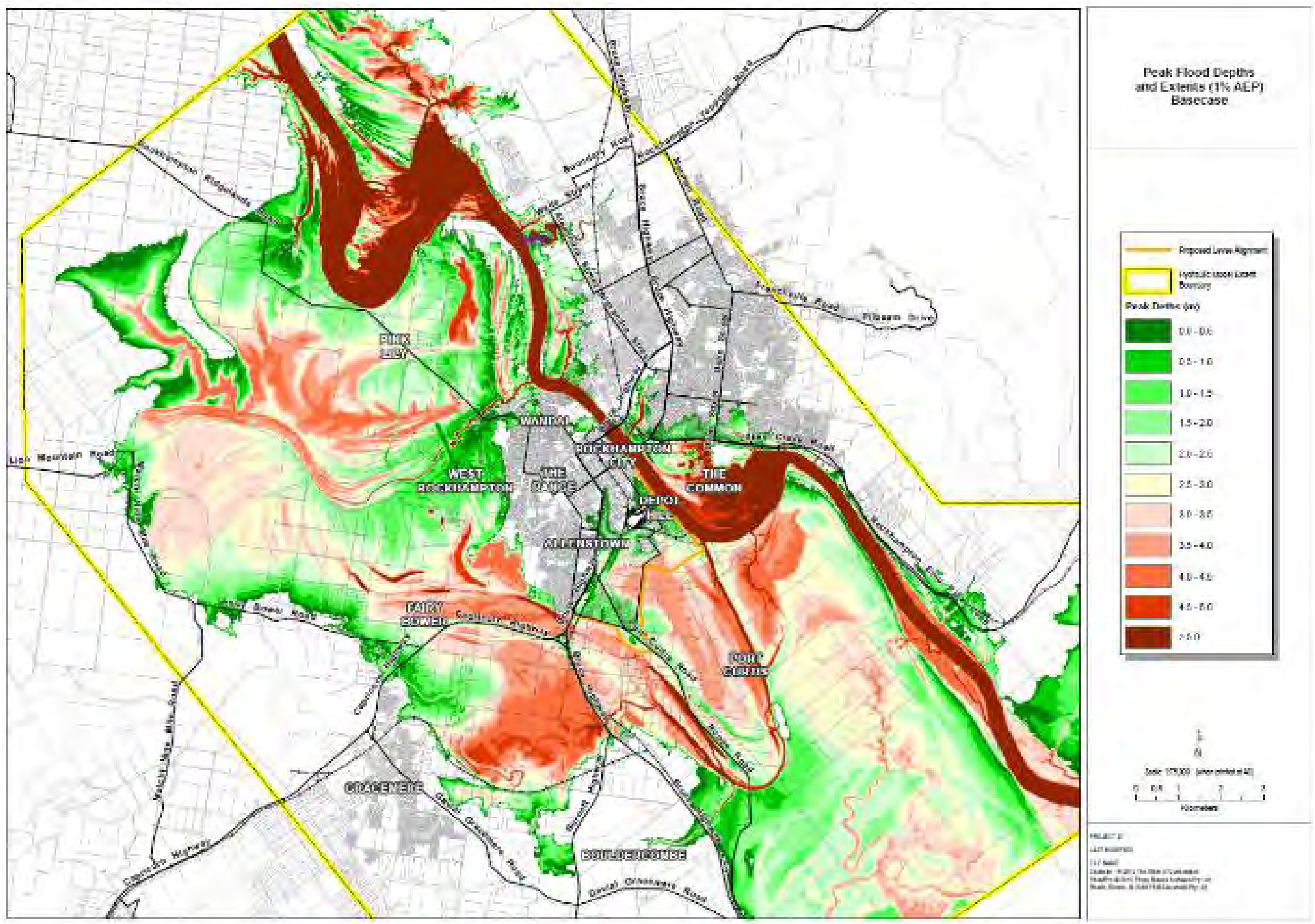
Peak flood depths (1% AEP)



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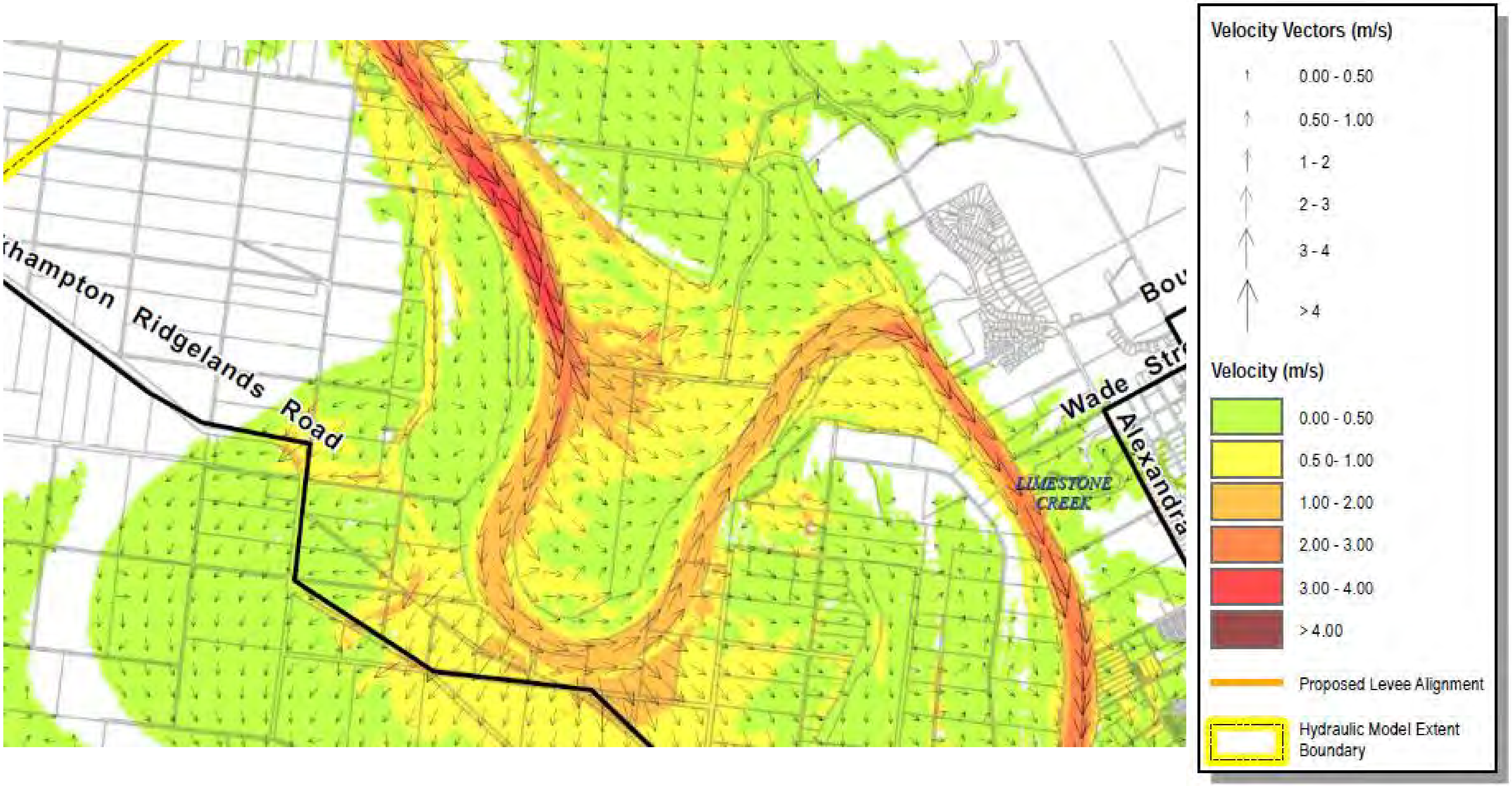
Velocity vectors



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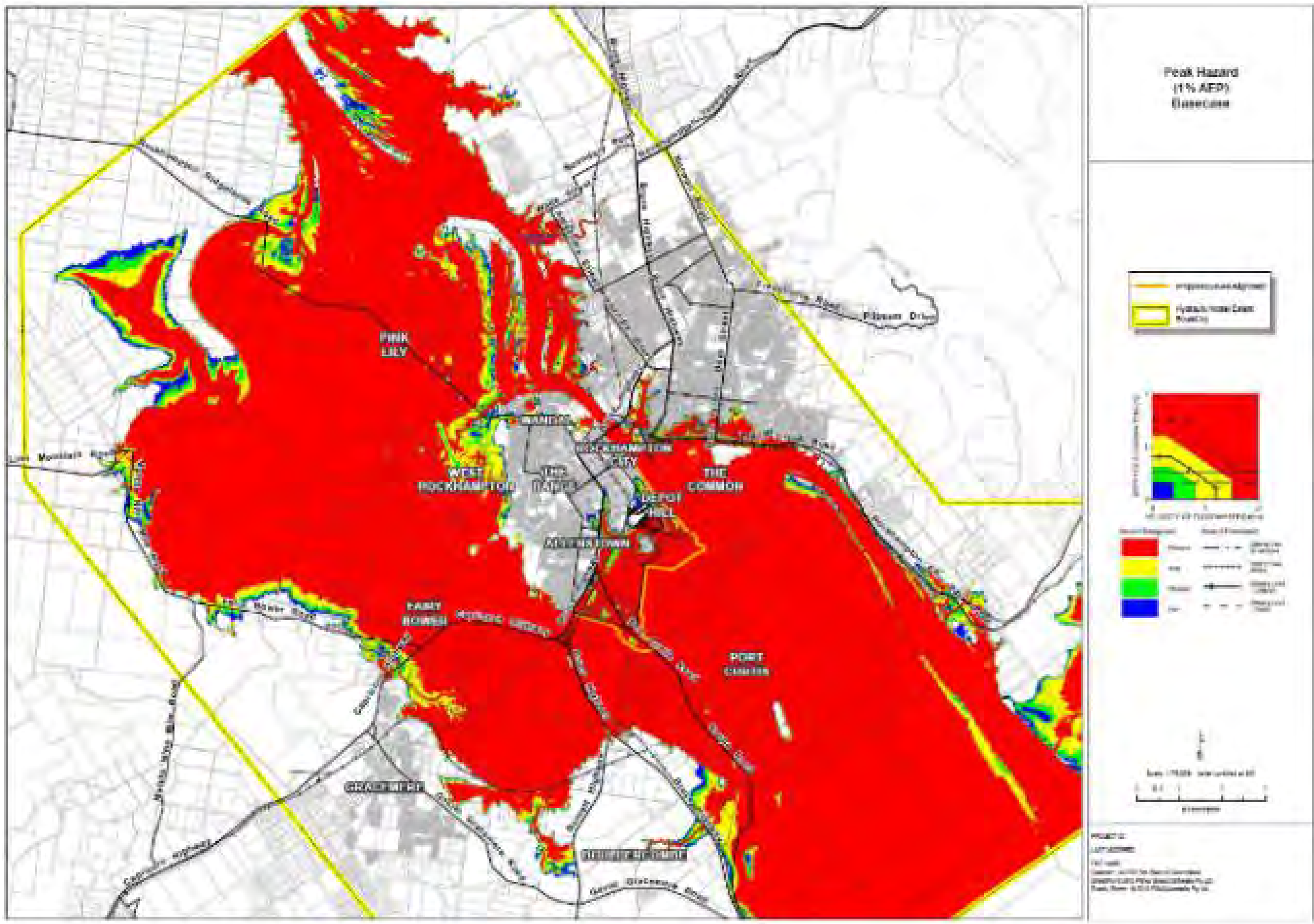
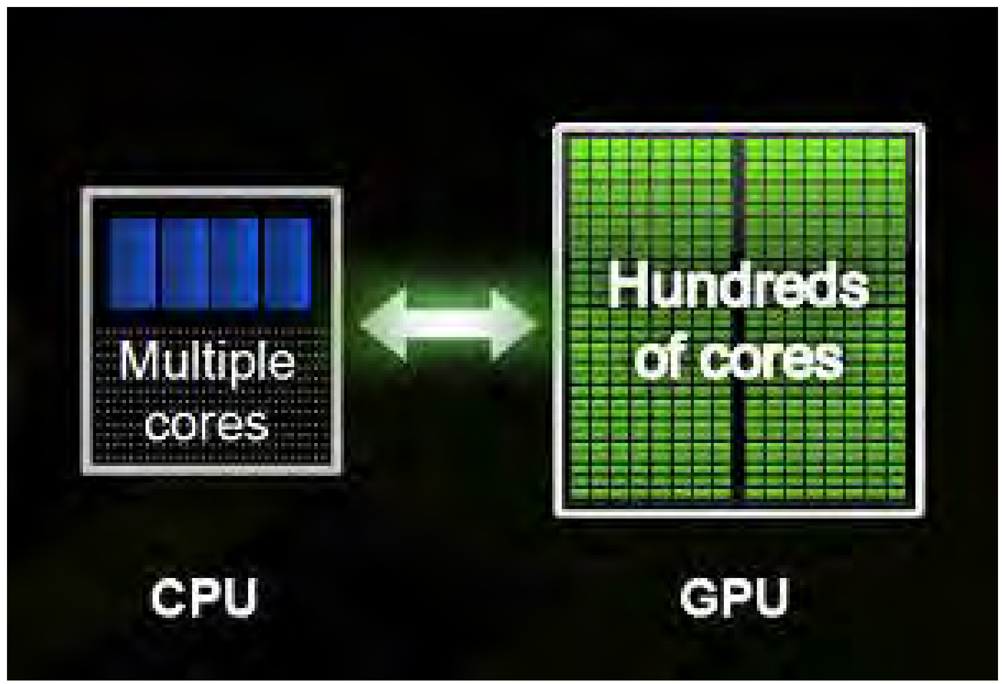
Hazard Categories



Advances in GPU Processors

- GPU - Graphics Processing Unit
- GPU enabled 2D models can see increases in speed of 30-100x (TUFLOW, MIKEFLOOD, ICM)
- Enables:
  - Extremely large scale flood assessment
  - Finer resolution modelling
  - Use of 2D in place of 1D



Large Scale Flood Modeling

– **Flinders Highway**
  - **~80,000 mi^2**
  - **80 Million Cells**
  - **Model Run Time: 4 hours**

U.S. Rank	State	Size (mi^2)
14	Idaho	83,570
15	Kansas	82,277
16	Nebraska	77,354
17	South Dakota	77,117

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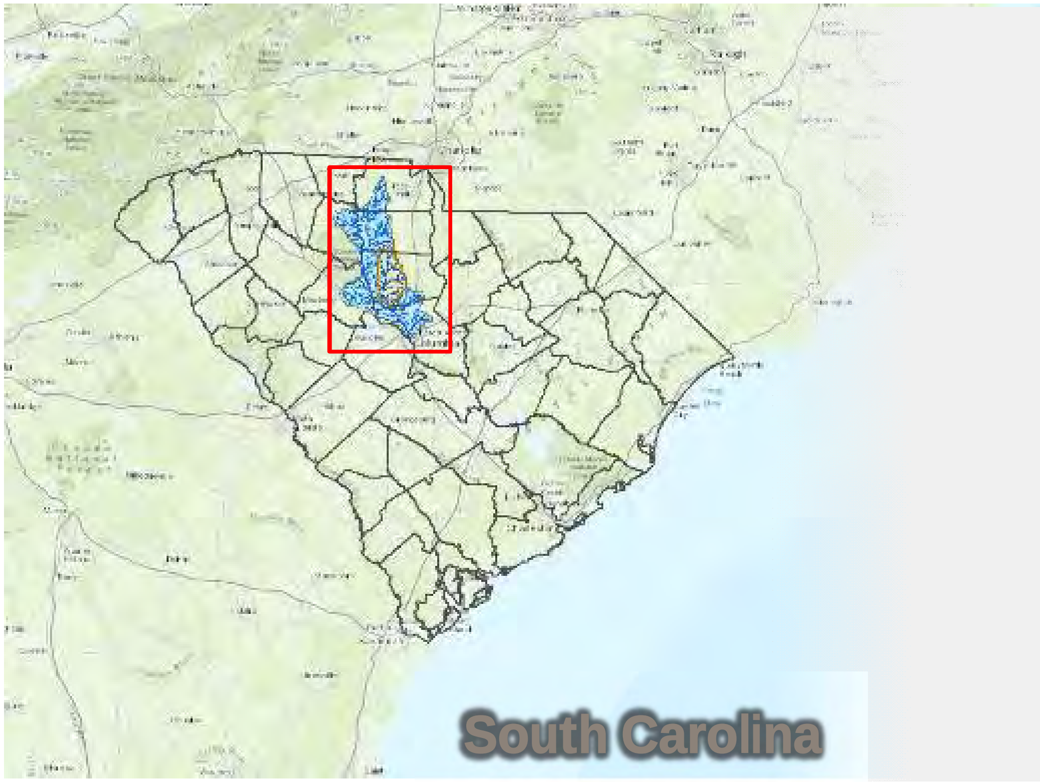
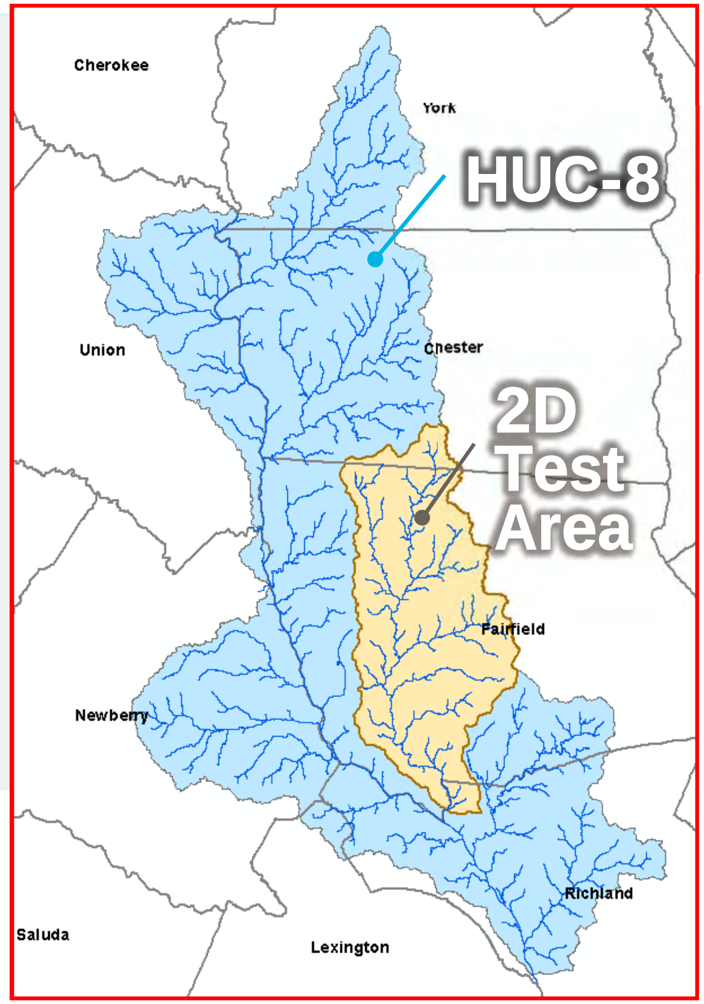
Direct rainfall for hydrology

Comparing 1D “approximate” vs 2D direct rainfall
Project Area #1: South Carolina





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Comparison of Area/Methodology

Overall Basin	
Area	1,289 mi^2
Approach	SwiftMAP (1D HEC-RAS)
Hydrology	USGS Regression Eqn.
Terrain	LIDAR
Model Stats	350 streams ~1,000 miles
Output	HEC-RAS, Boundaries, Depth/WSE/Pct Chance Grids

2D Sub-basin	
Area	250 mi^2
Approach	TUFLOW GPU (2D)
Hydrology	rain-on-grid; 24-hr SCS Type II distribution, 8.3 inches for the 1% event (from NOAA Atlas 14)
Terrain	LIDAR
Model Stats	17 million cells at size of 6 meters
Output	Depth/WSE/Velocity Grids, Hazard/Severity

60-90% reduction in labor to produce 2D results

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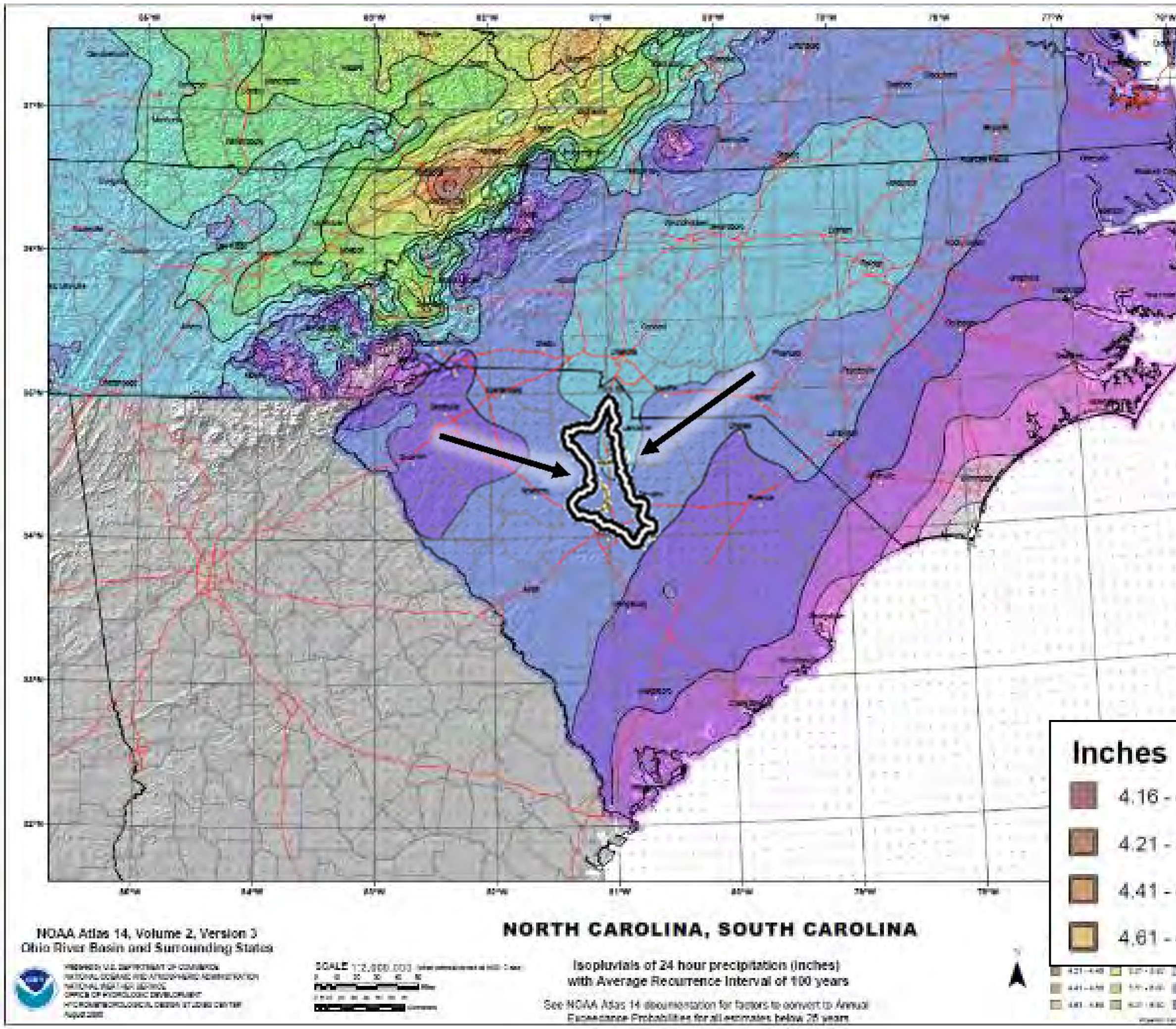
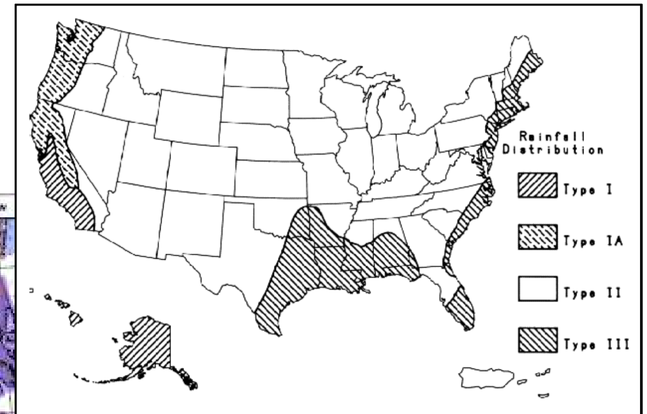
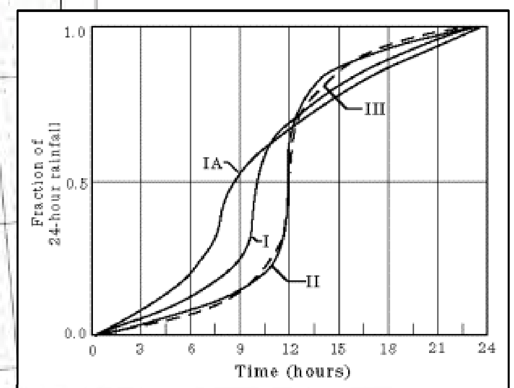
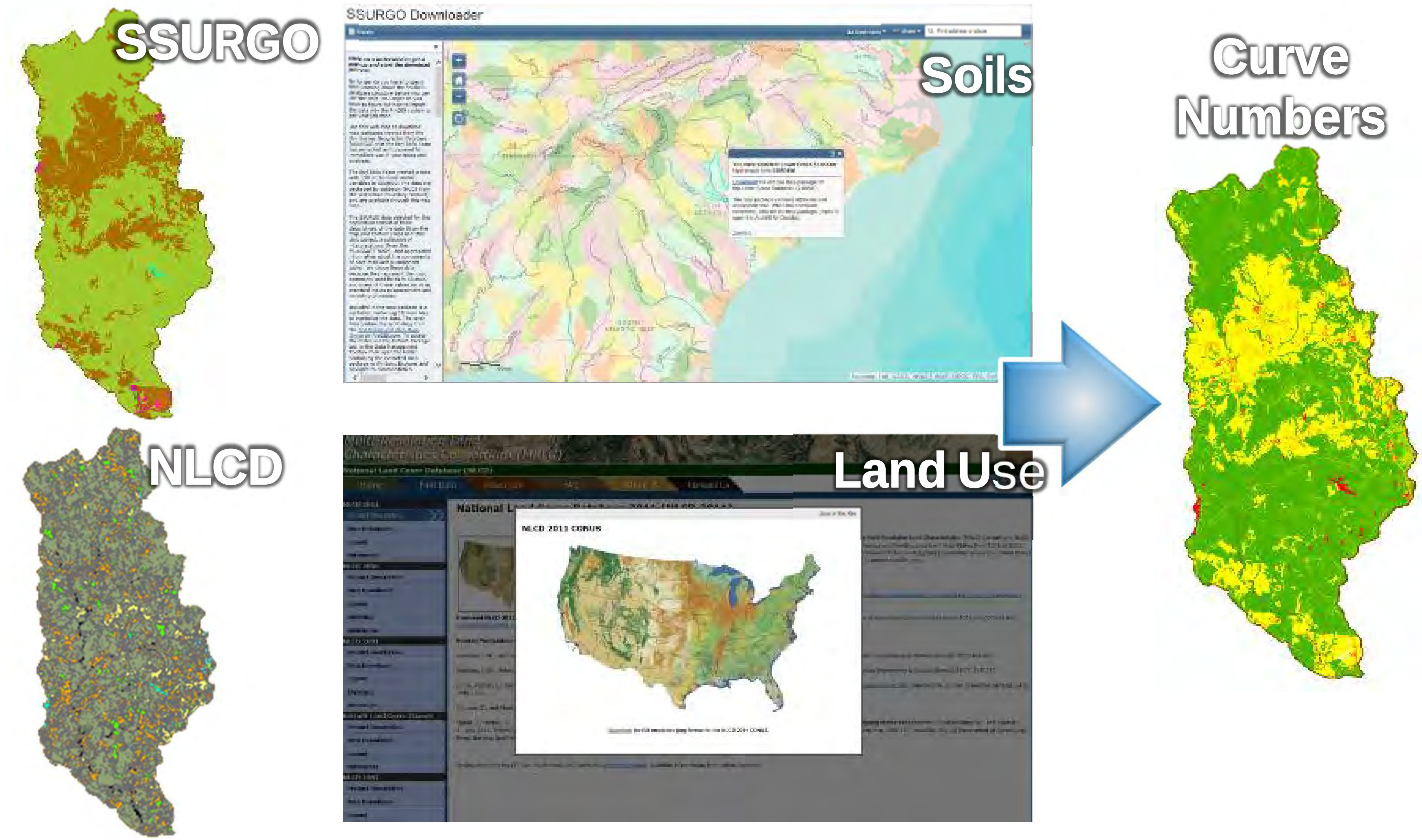
South Carolina 2D Model: Hydrology - Rainfall







South Carolina 2D Model: Hydrology - Losses



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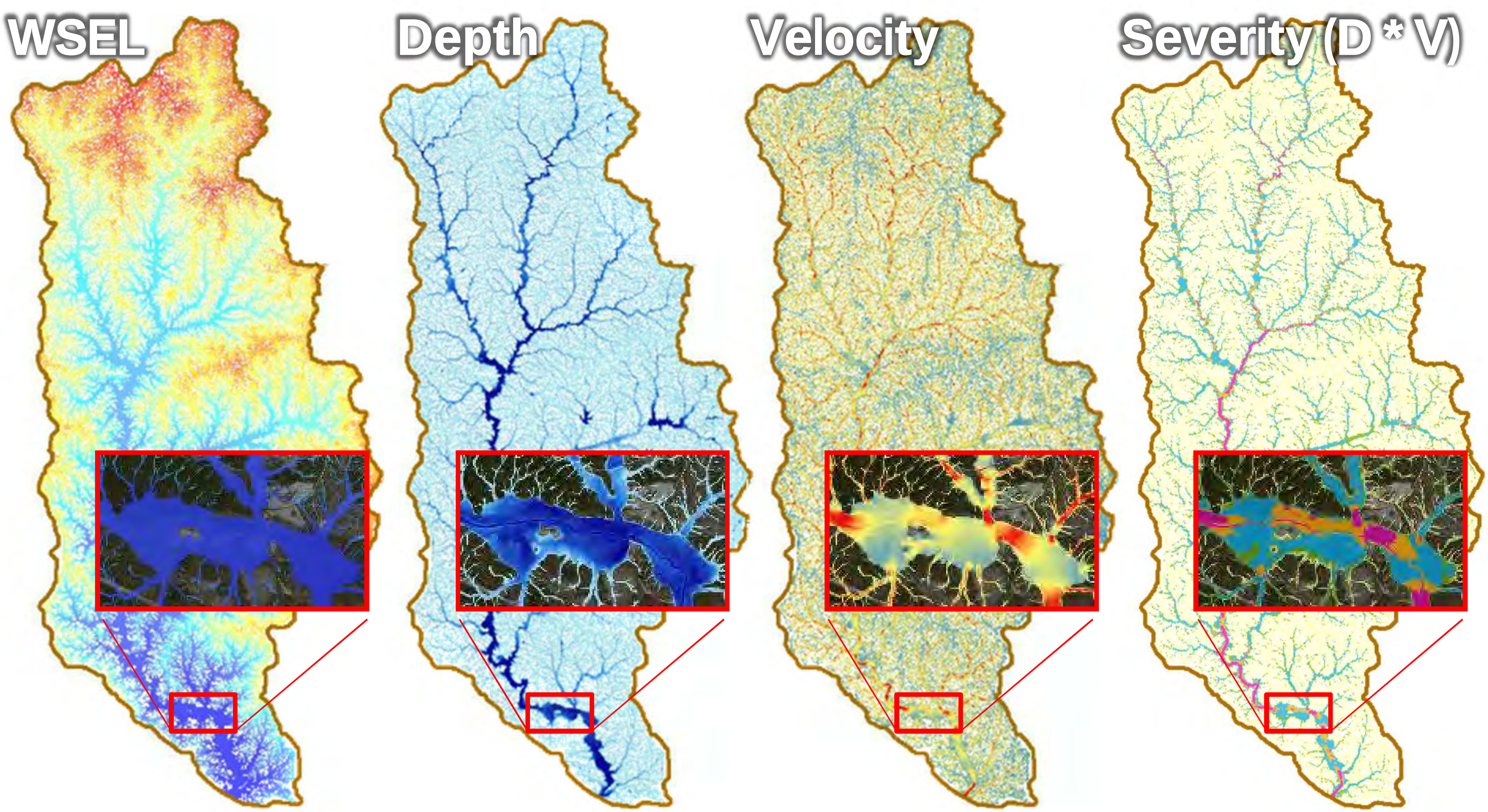
South Carolina:
2D Model Output



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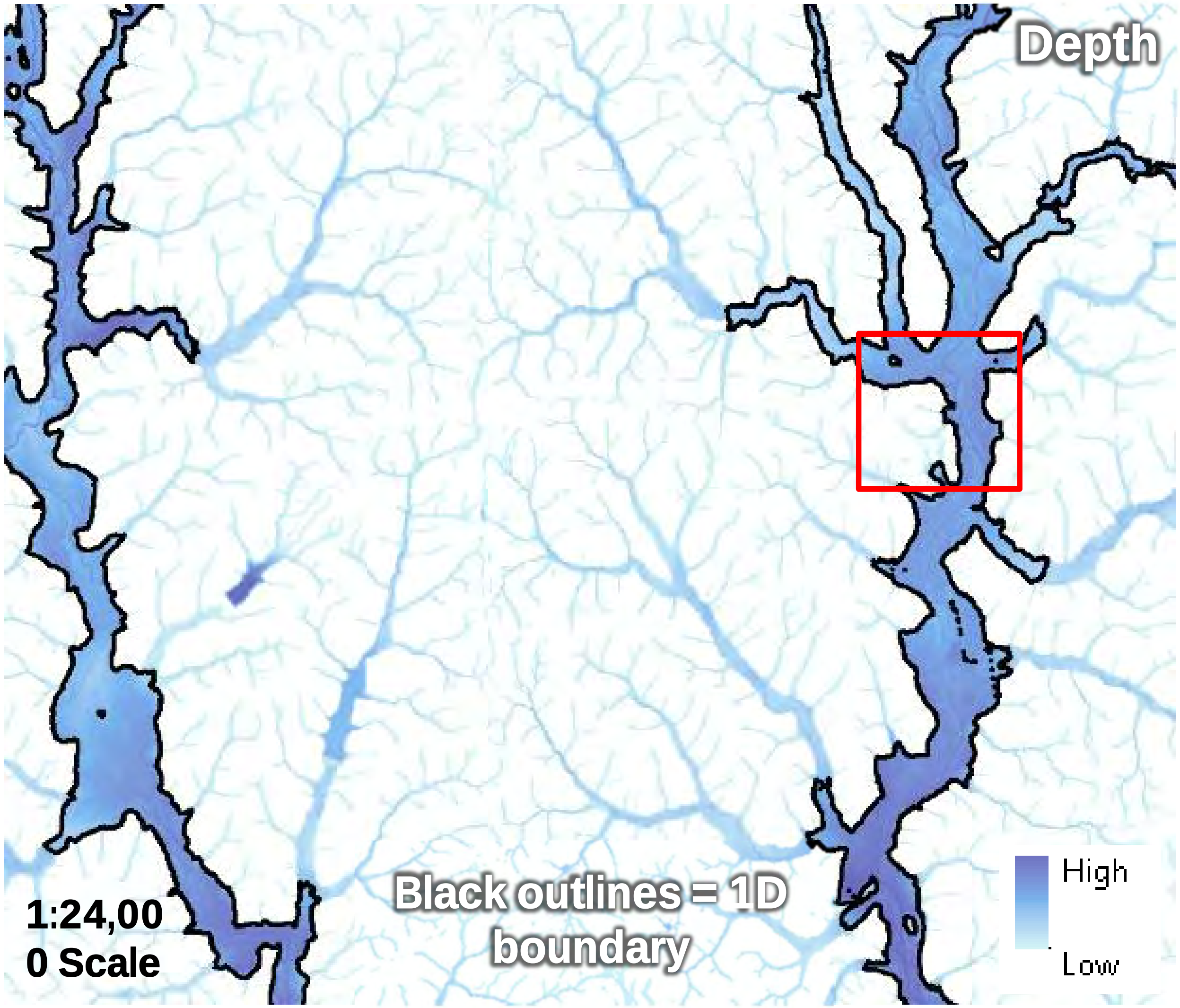
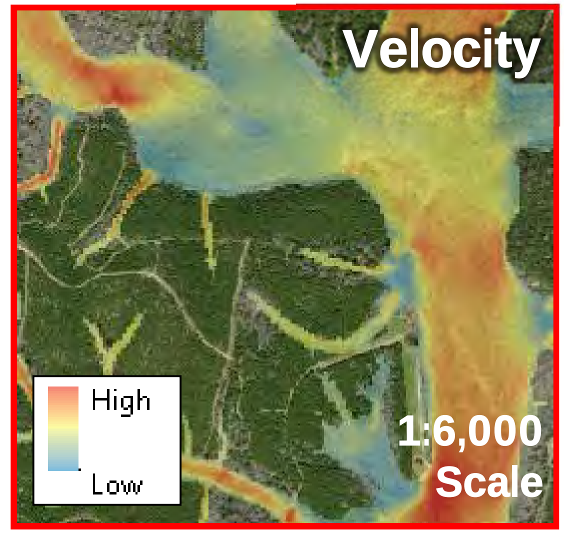
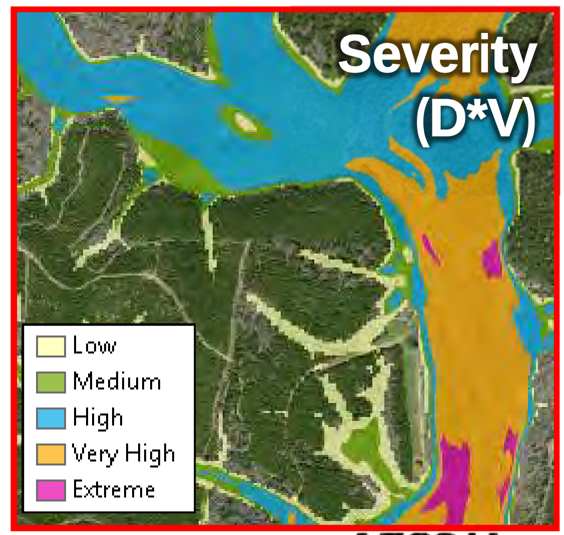
South Carolina:
Mapping Comparisons







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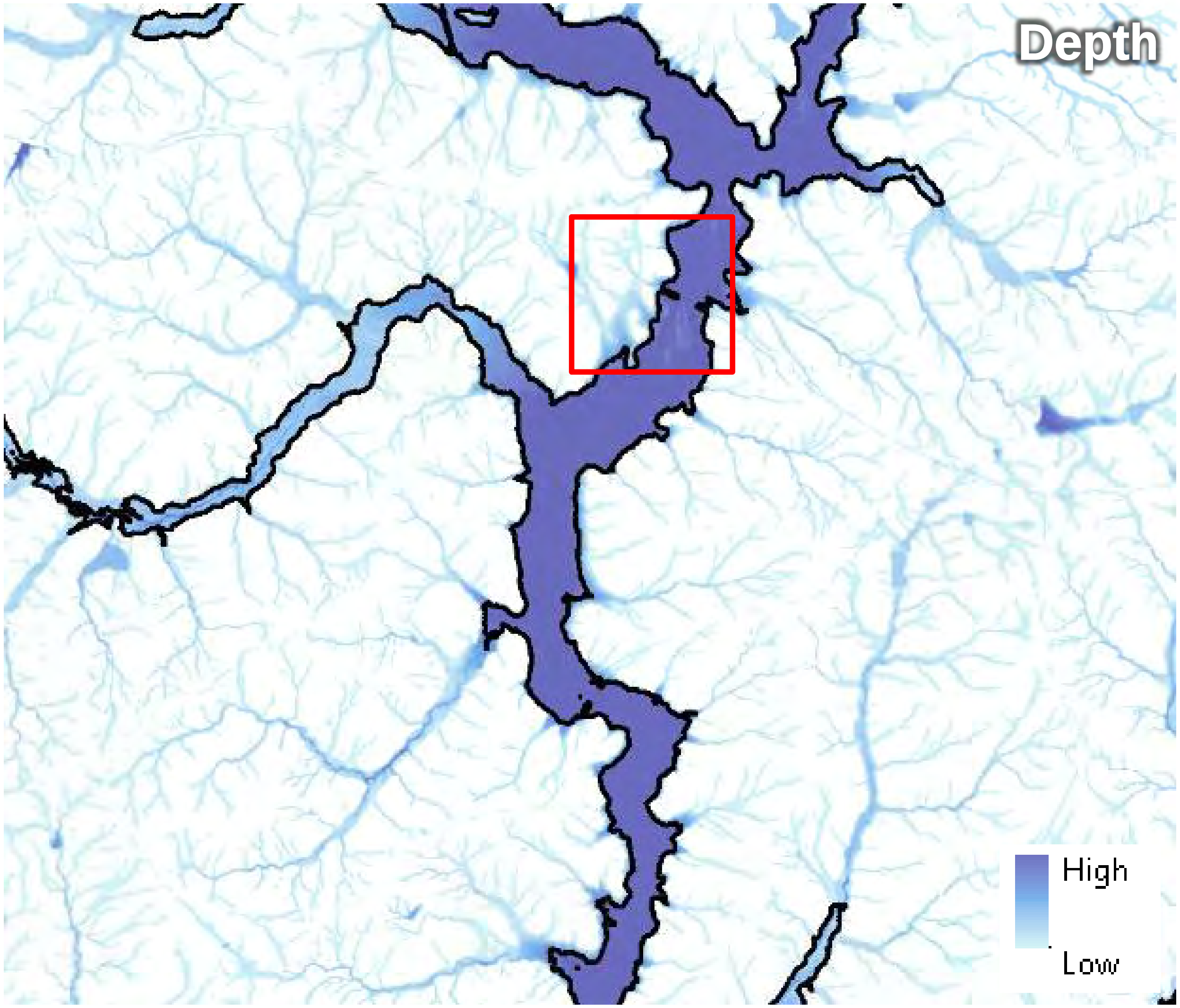
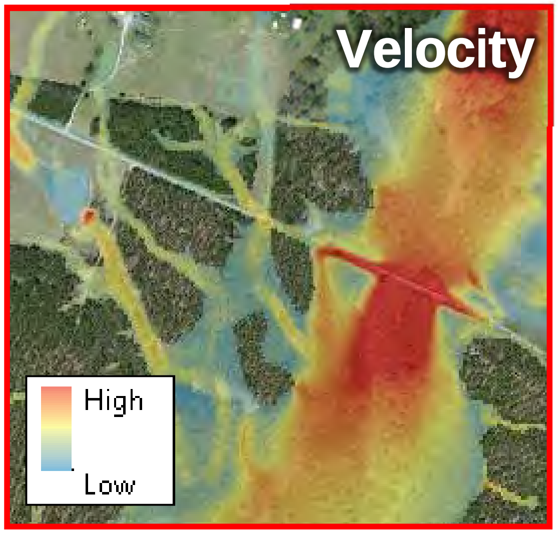
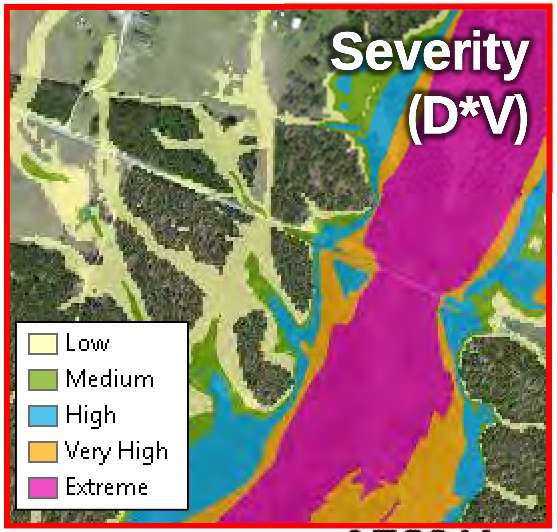
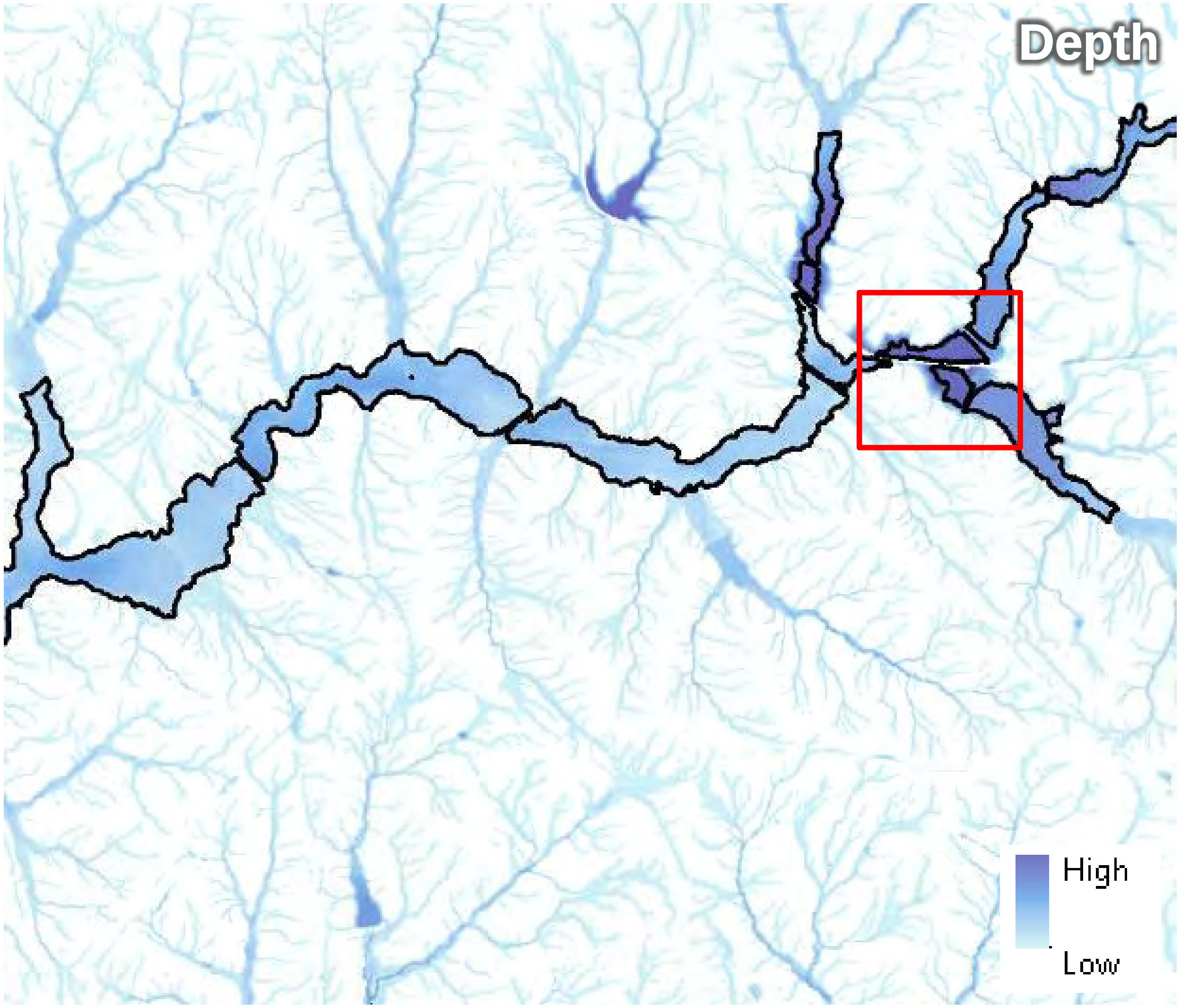
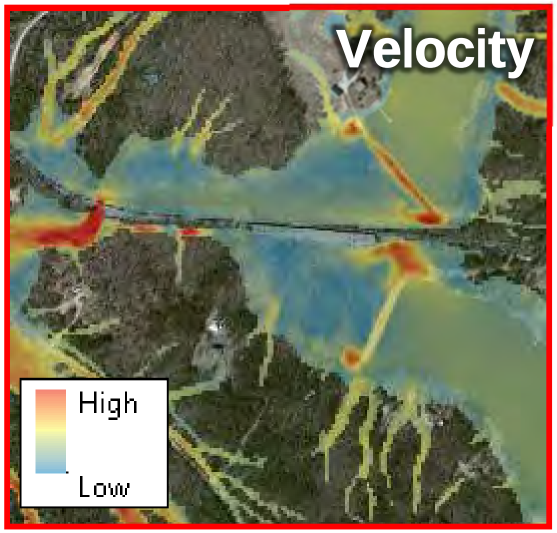


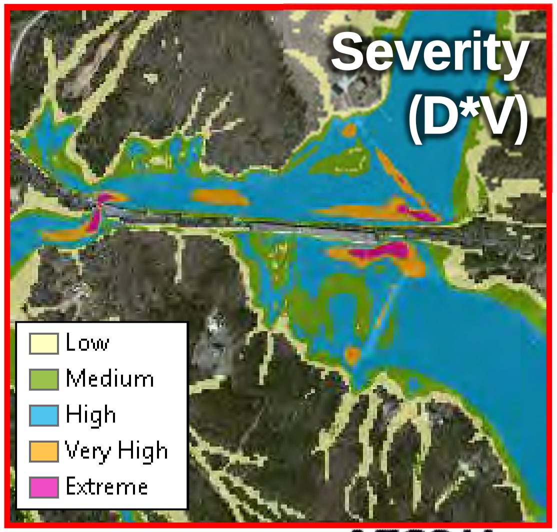




South Carolina: Mapping Comparisons







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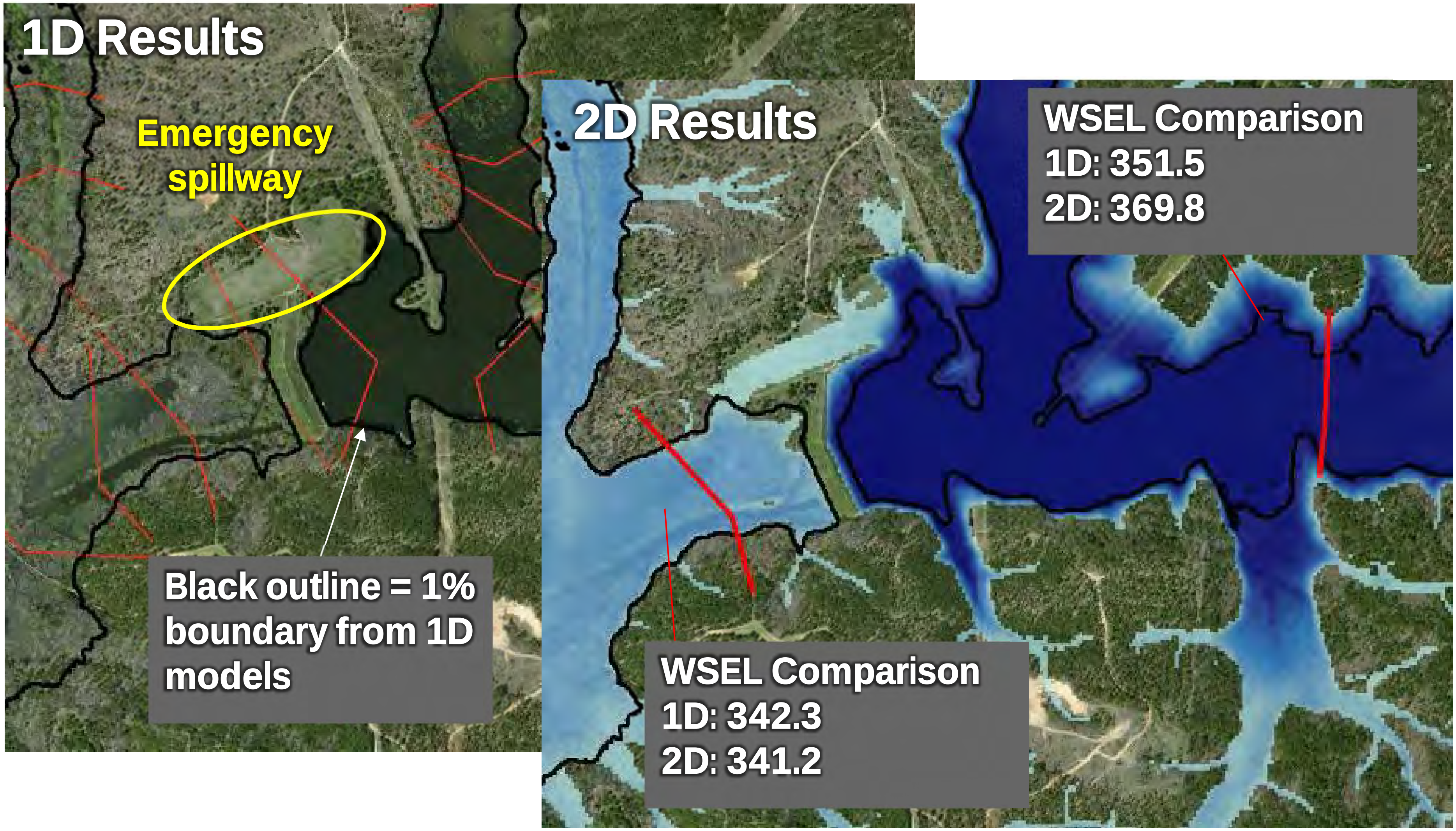
2D vs. 1D approximate comparison: Dam 1



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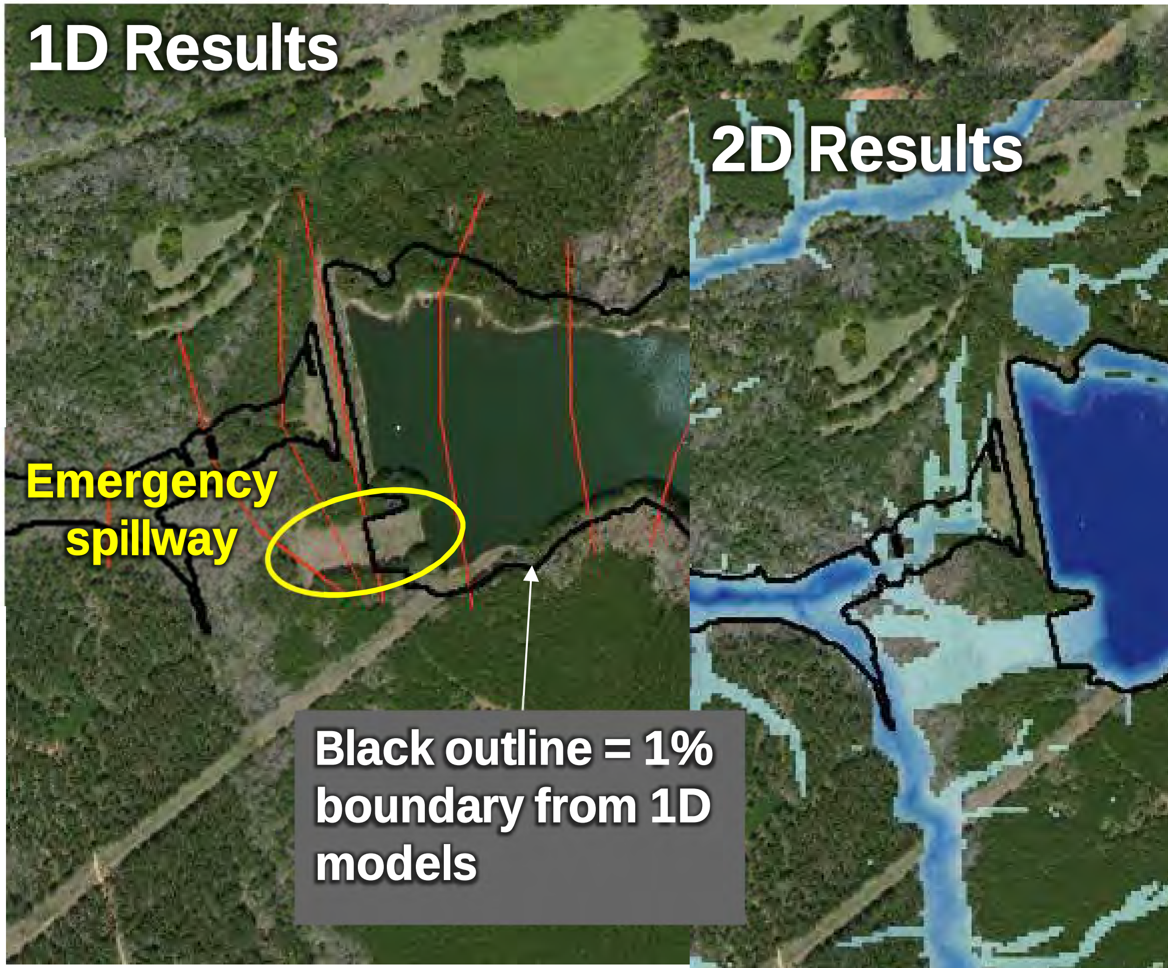
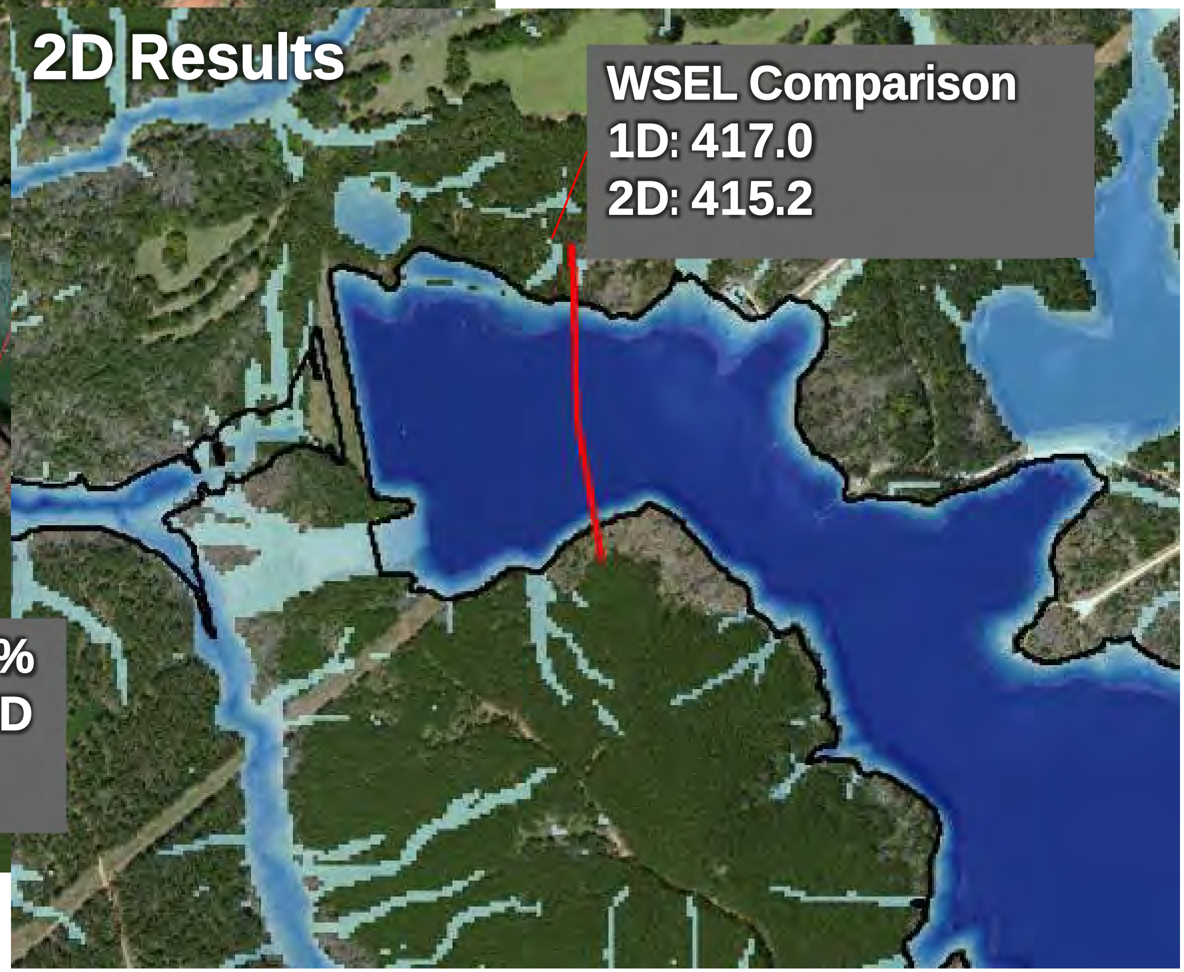
2D vs. 1D approximate comparison: Dam 2





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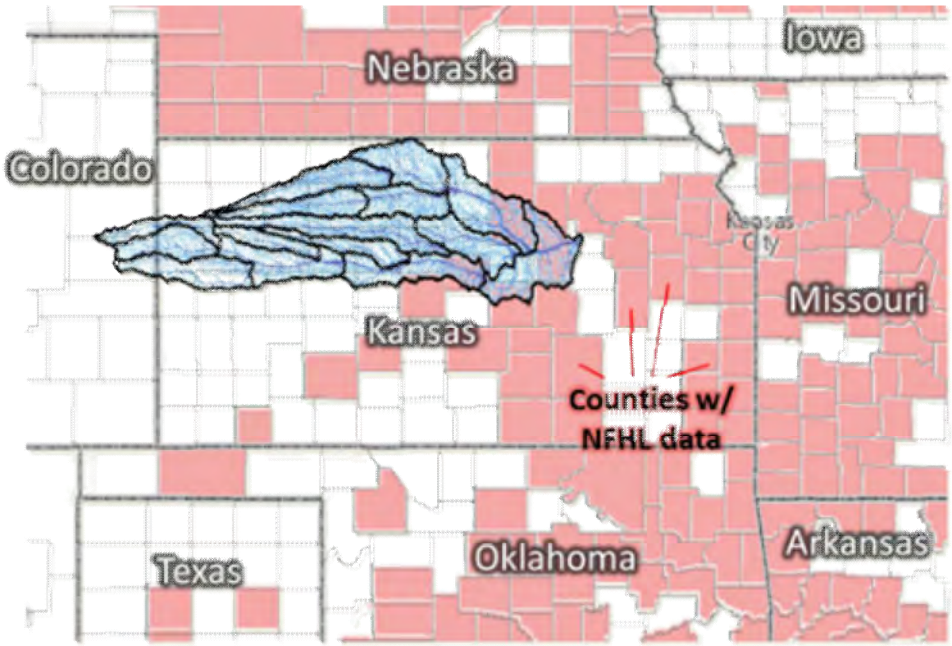
Pilot Area #2: Western Kansas

2D Sub-basin	
Area	20,000 mi^2
Approach	TUFLOW GPU (2D)
Hydrology	rain-on-grid; 24-hr SCS Type II distribution, 7.3 inches
Terrain	USGS 10 m DEM
Model Stats	32 million cells at size of 40 meters
Output	Depth/WSE/Velocity Grids, Hazard/Severity
Labor Time	40 hrs
Run time	3.5 hrs



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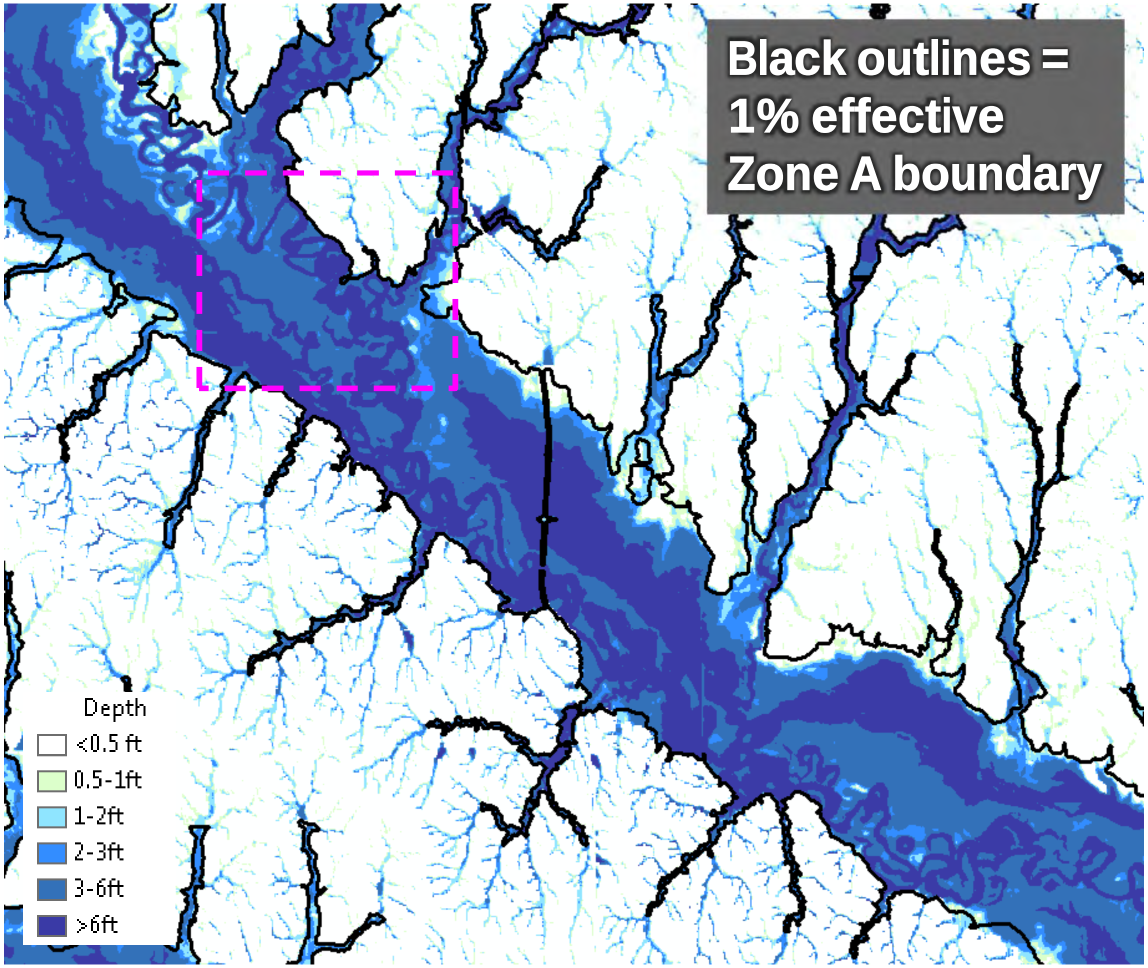
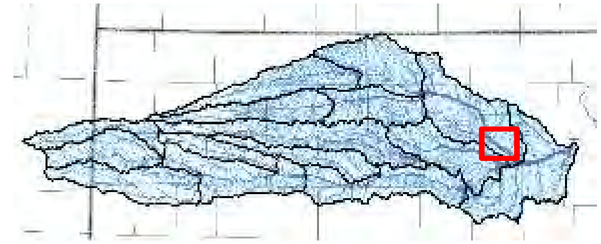
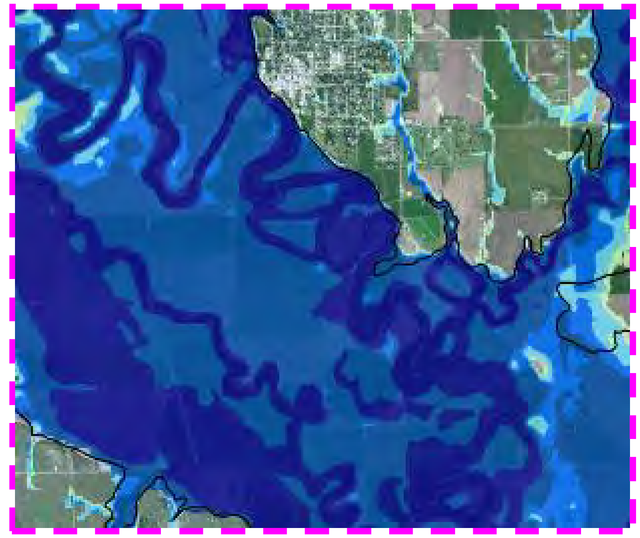
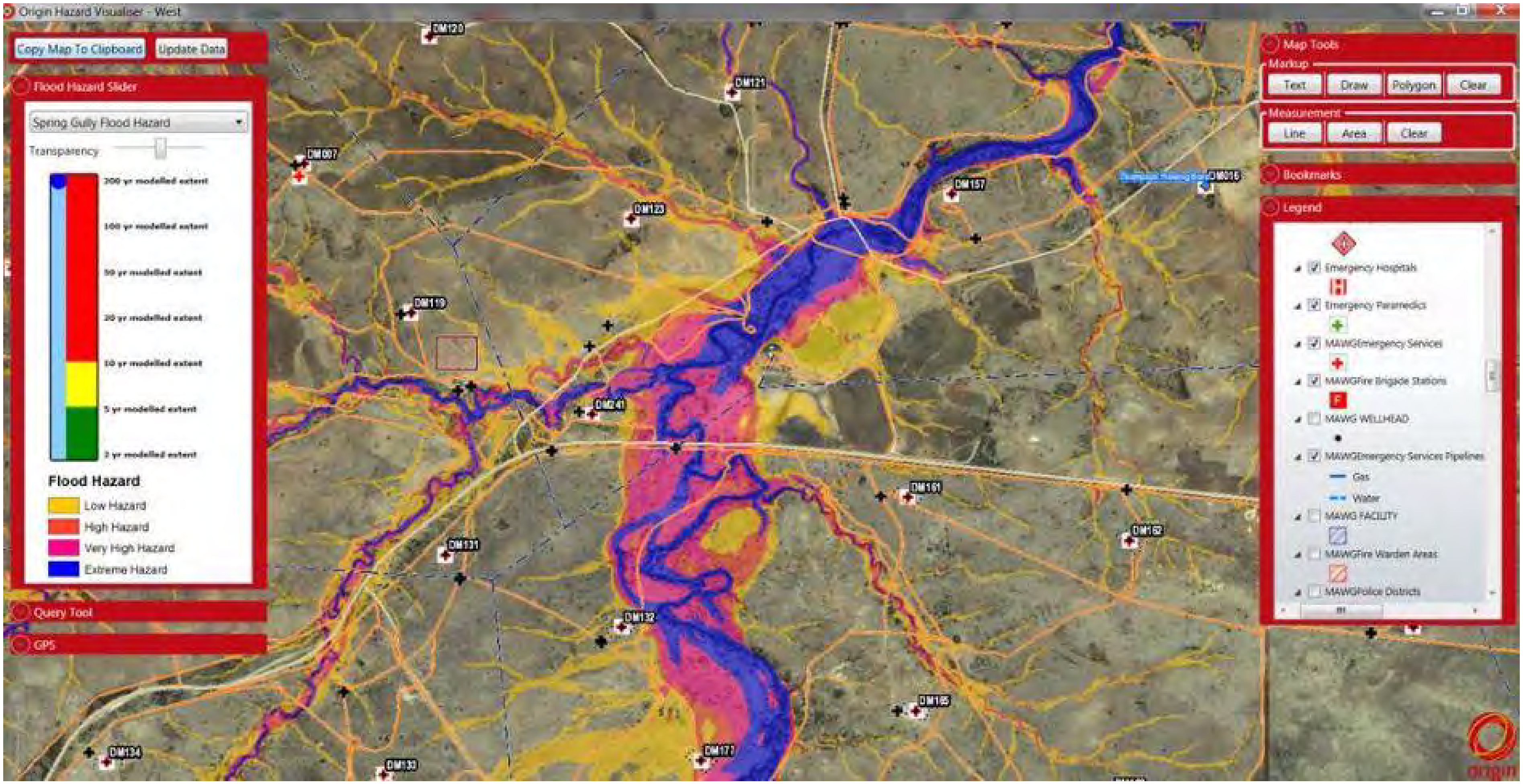
Western Kansas: Comparisons







Broad scale infrastructure risk assessments



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Broad scale infrastructure risk assessments

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Conclusion

- **Todays 2D models:**
  - **Are GPU enabled and faster**
  - **More user friendly**
  - **Provide coupled 1D-2D**
  - **Easier to use**
  - **More cost effective**
- **The models provide a range of output data sets and options that can provide added value in the area of flood risk management and emergency management**
- **A wide range of models are available, each with strengths in different areas geared towards different challenges – choose a model based on project goals**

Thank You

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