Urban Floodplain modeling- Application of Two-Dimensional Analyses to Refine Results

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Hydraulic modeling of urban areas and issues

- Modeling of urban areas present complex challenges than those for rural areas

- Most of the developed areas are along the border of water courses

- Require consideration of built up areas, highly varying land use, narrow flow paths, underground storm water drainage.

- With the overbanks developed with roads and buildings, urban areas generally exhibit flat topography

- When the flow overtops the channel into overbanks, the flow finds its own flow paths to reach the ocean.

- In some cases the overbank floodplain may be disconnected from the channel flow/ can exhibit flow exchange.

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Why Two-dimensional Models to model urban areas

- When topography is flat and direction of the overbank flow paths distinctly differ from the channel direction the flow is two-dimensional

- Improves the accuracy of final floodplains and floodways computed

- RMA-2, FESWMS, FLO-2D, MIKE Flood; others

- Increasing interest and use

- Better data, and quality

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Governing Equations

- Equations of Motion
  - Depth-Averaged Equations Of Motion
  - Conservation of Mass - continuity
  - Conservation of momentum in two horizontal directions
- Solution Method
  - Finite difference Solution
    2-D grid is used to represent the topography
    FLO-2D, MIKE-21
  - Finite element solution
    Irregular finite element mesh to represent topography
    RMA-2V, FESWMS, MIKE-21, XP-SWMM-2D

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- Boundary Conditions
  - Steady Flow
    Constant discharge applied
  - Unsteady Flow
    Discharge varies with time
    Hydrograph is applied
- Calibration
  - Calibration of the model is recommended
  - If the flow is 2d, then an uncalibrated 2d model represents the flow patterns better than a 1 d model.
- Interpreting Results
    FD solution: Flow parameters computed at center of grid
   FE solution: Flow parameters computed at nodes of elements

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Physical Processes simulated in a 2D model

PHYSICAL PROCESSES SIMULATED BY FLO-2D
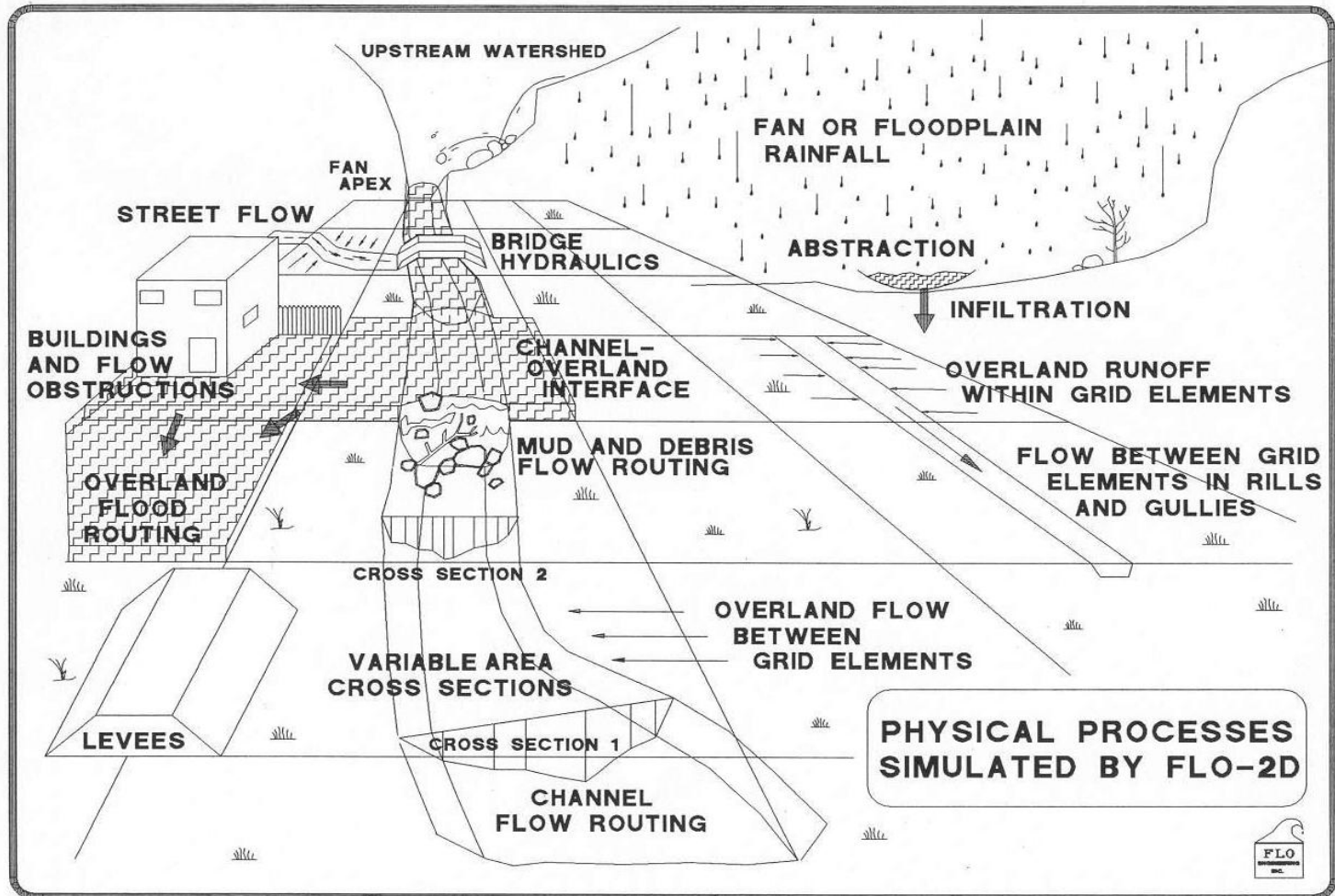
Advantages of 2 D simulation

- Accounts for transverse components, using depth average equations of motion

- Flow paths can be identified by flow velocities, flow rate and volume computed in the grid.

- Simulation of the hydraulic interactions between the channel and floodplain (2d/1d models)

- Ability to employ fine model resolution near critical floodplain features (FEM models)

- Improved analysis of floodplain and overbank flows through a better definition of physical situations

- Easier to develop other Risk MAP products like depth & velocity grids

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Velocity Vectors to define flow paths
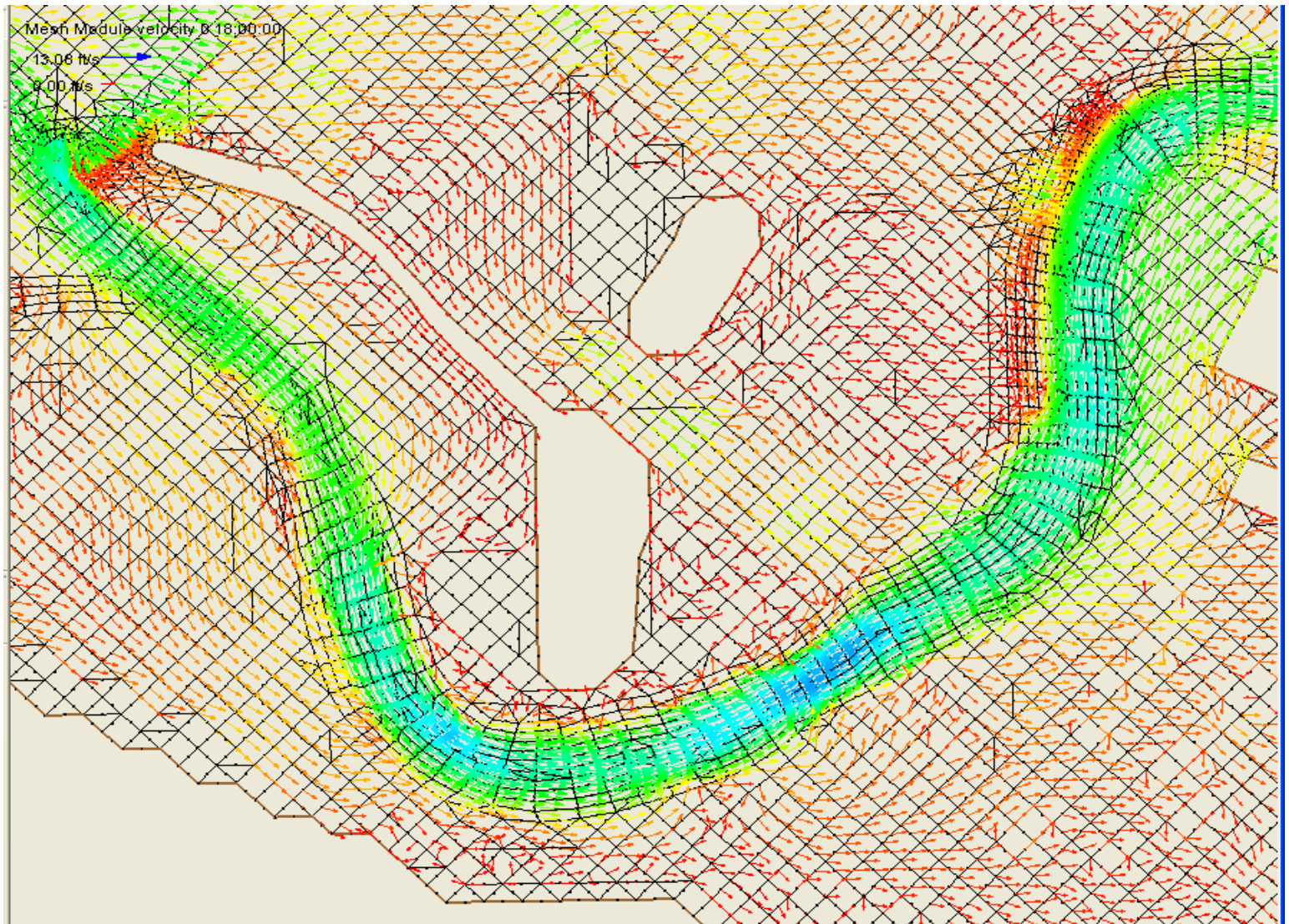
Disadvantages

- Loss of channel definition

    1-d embedded solution(Flo 2d, XP, DHI)

- More advanced data requirements

- Direction of split flows and magnitudes have to be determined

- Difficulty in data integration

- Longer computation times

- Expensive both in terms gathering data and final output

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Alternate solutions

- Alternatively, steady flow one-dimensional solution can be developed with the aid of a steady flow two dimensional analysis, where the two-dimensional model results are used in identifying the major flow paths within the floodplain.

- Applicable in split flow conditions

Current NFIP Guidance

- Appendix C: Riverine Flooding Analysis and Mapping
  - C.3.3.3:
- Appendix E: Shallow Flooding Analysis and Mapping
  - Flood zones
  - E.4: Ponding (AH) versus sheet runoff (AO)
  - E.5.3: Sheet runoff
    "…average of all the average flow depths at all cross sections with a selected reach length…"
  - E.5.: "…where the slope of the water surface is extremely low and uniform BFEs can be established for large land areas, Zone AH with a BFE is preferred."

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Issues in the FW model

- Due to very narrow and split flow channels the FW are usually very wide.

- The use of ineffective flow areas on the overbanks increase the base flood elevations in the vicinity.

- Usually the flooding due to the split flows the depth is usually in between 1-3ft (AO zone)

- Some times in many areas due to the flat topography and wide floodplains, the areas are modeled as Zone A's
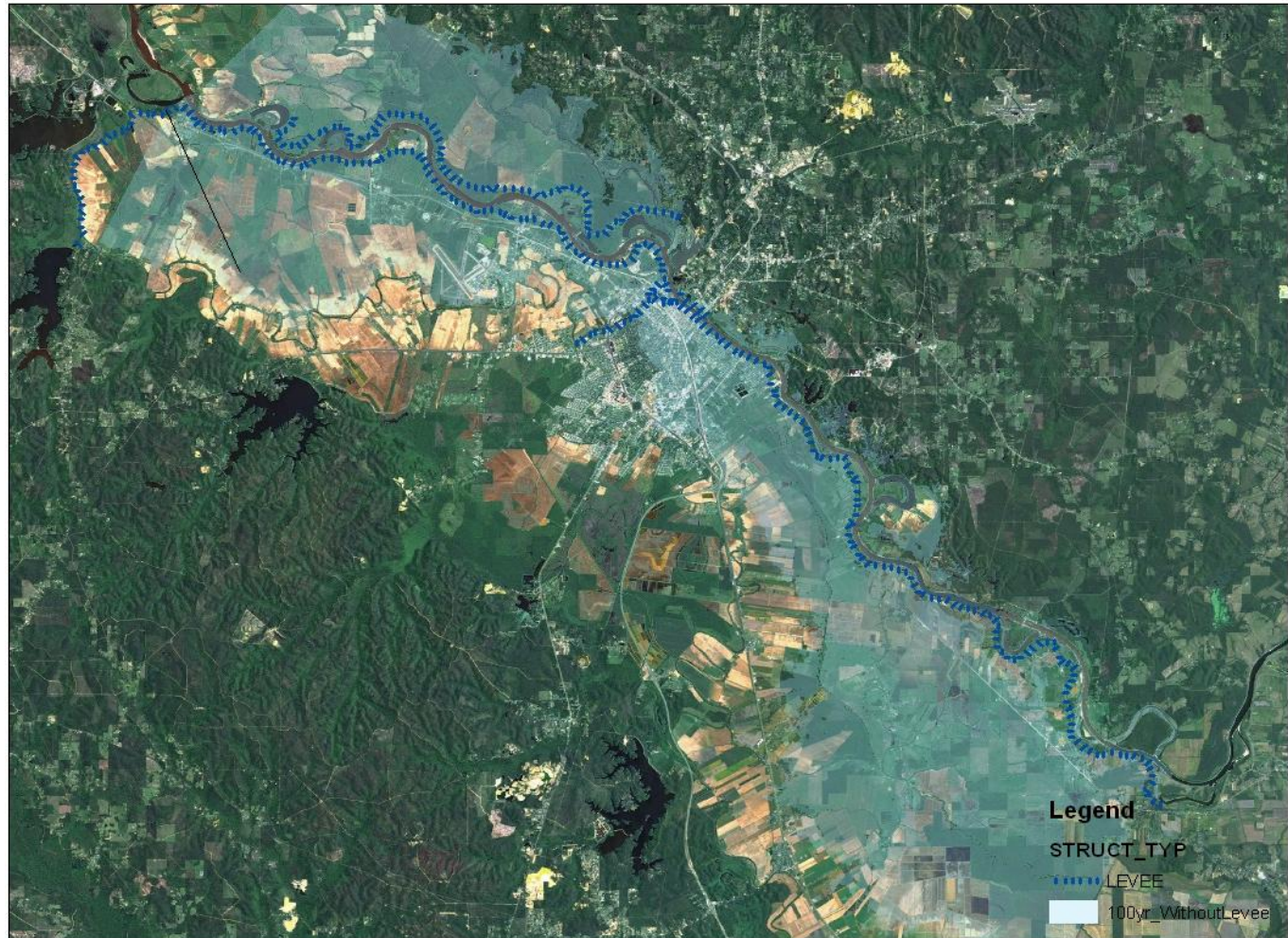
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Gwynn's Falls, Baltimore

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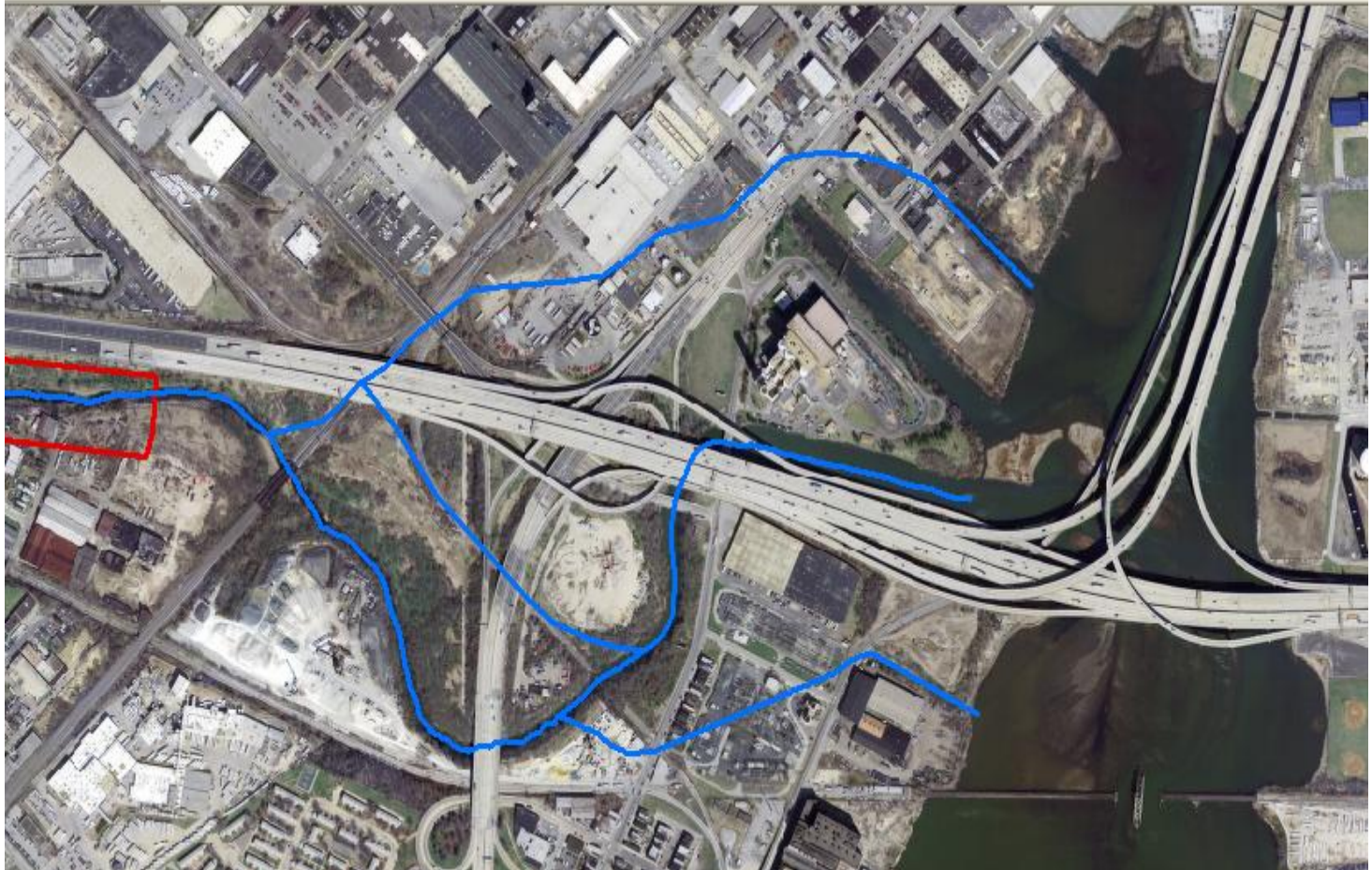
Rio Grande De Loiza, PR

Red River, Rapids County, LA

Conclusions

- Where ever the flow is two- dimensional, 2 d analysis gives better results
- If effective is a 2d study, new analysis should also be 2d
- Can be cost effective
- Can be used to refine the 1d results for sensitive areas.
- Calibration is highly recommended for the models

Questions?