2019 OHIO STORMWATER CONFERENCE 12th Annual

ARCADIS Design & Consultancy for natural and built assets

DYNAMICALLY COUPLING ENHANCED 1-D SEWER NETWORK AND 2-D SURFACE ROUTING FOR URBAN DRAINAGE

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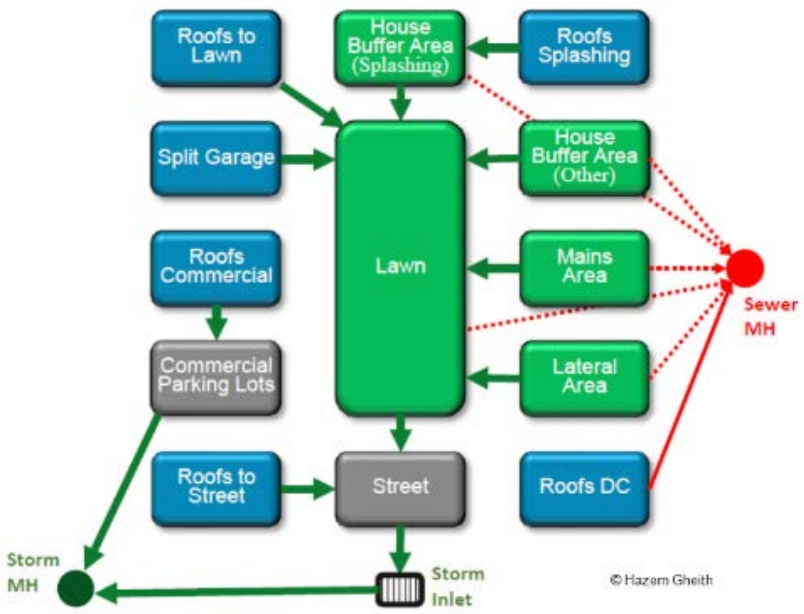
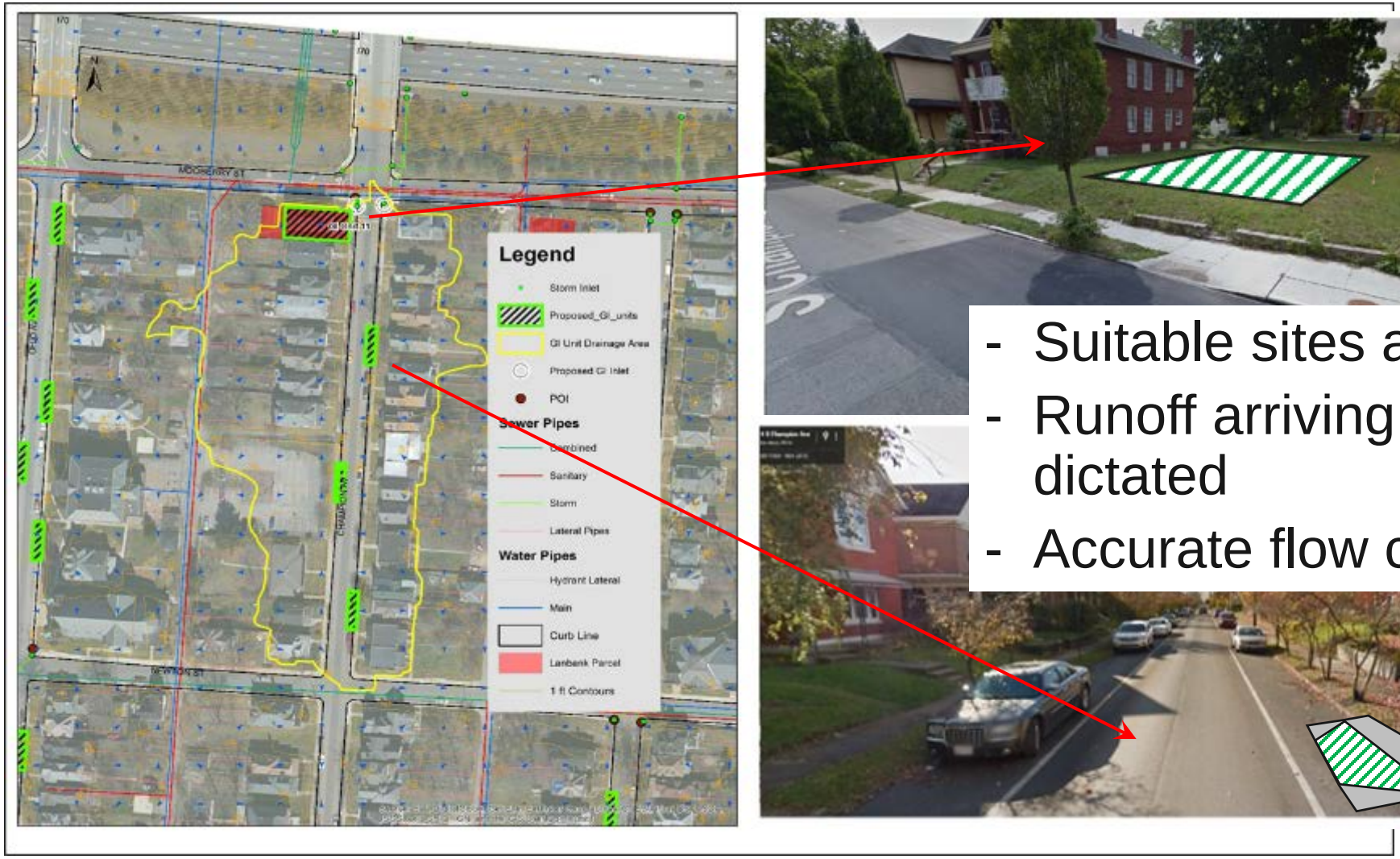


- H/H Modeling
- Collection System Master Plan
- CSO/SSO Mitigation
- GI Planning and Implementation

Green Infrastructures in Urban Setting



- Suitable sites are limited
- Runoff arriving at the site is dictated
- Accurate flow calculation is critical

Traditional Approaches for Modeling Urban Drainage

Rational Method

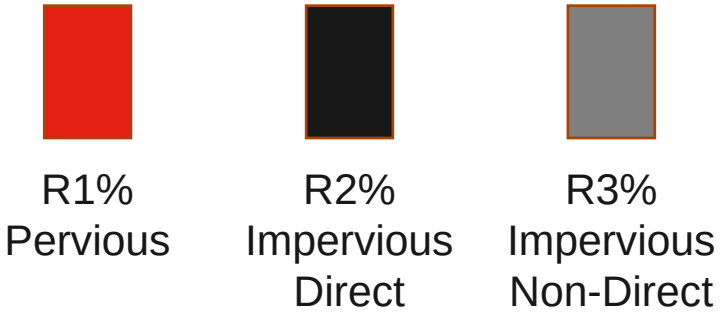
Runoff = C * Rain Intensity * Contributing Area

- Maximum flow only
- No flow routing mechanism
- Minimum consideration to topology/depressions
- No AMC (seasonal impact and back-to-back storms)

Fixed Percentage Approach:

Runoff(t) = R% * Rain(t) * Contributing Area

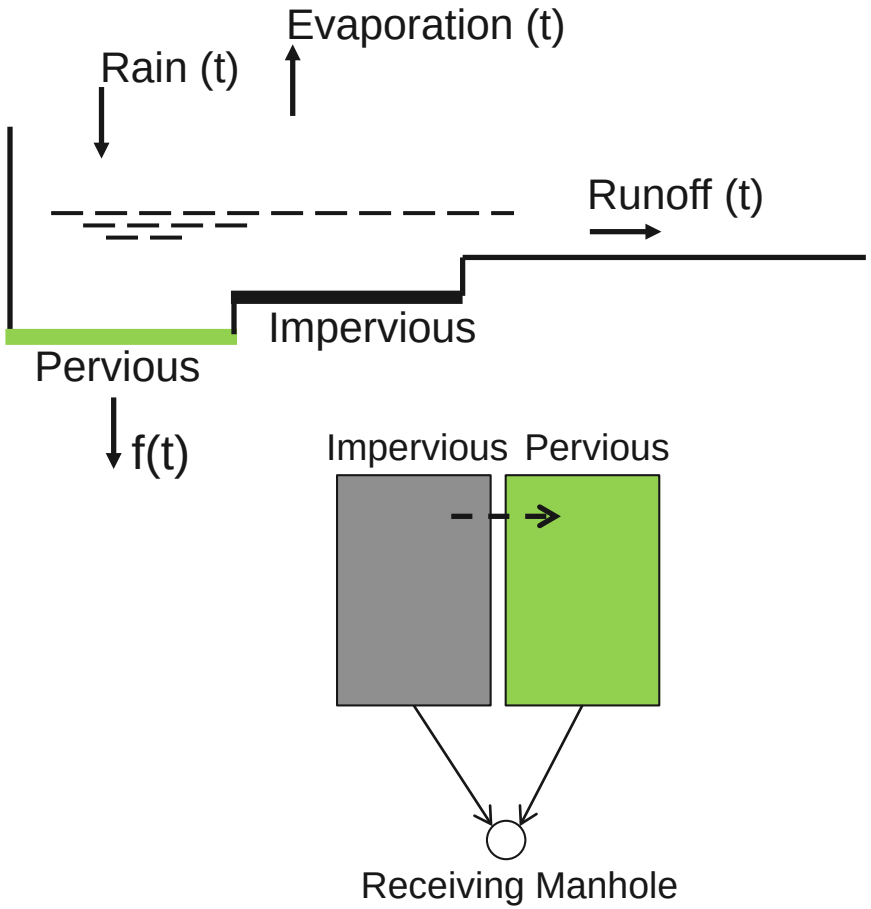
- No routing mechanism
- Minimum consideration of topology
- No AMC



Traditional Approaches (continued)

SWMM Approach

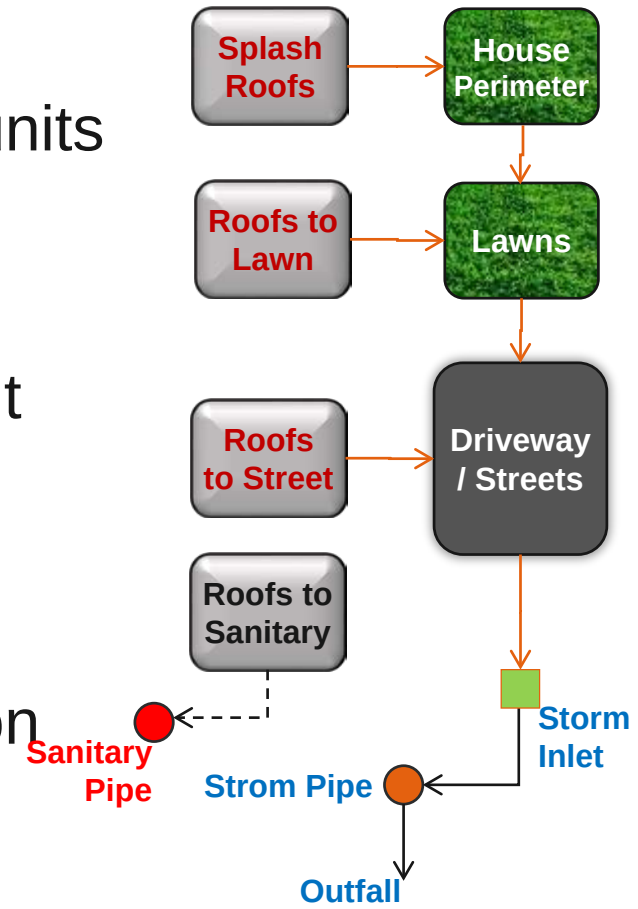
$$\text{Runoff}(t) = \frac{1.49}{n} * S^{1/2} * \frac{Contributing\ Area}{Flow\ Length} * (h(t)\text{-}D)^{5/3}$$



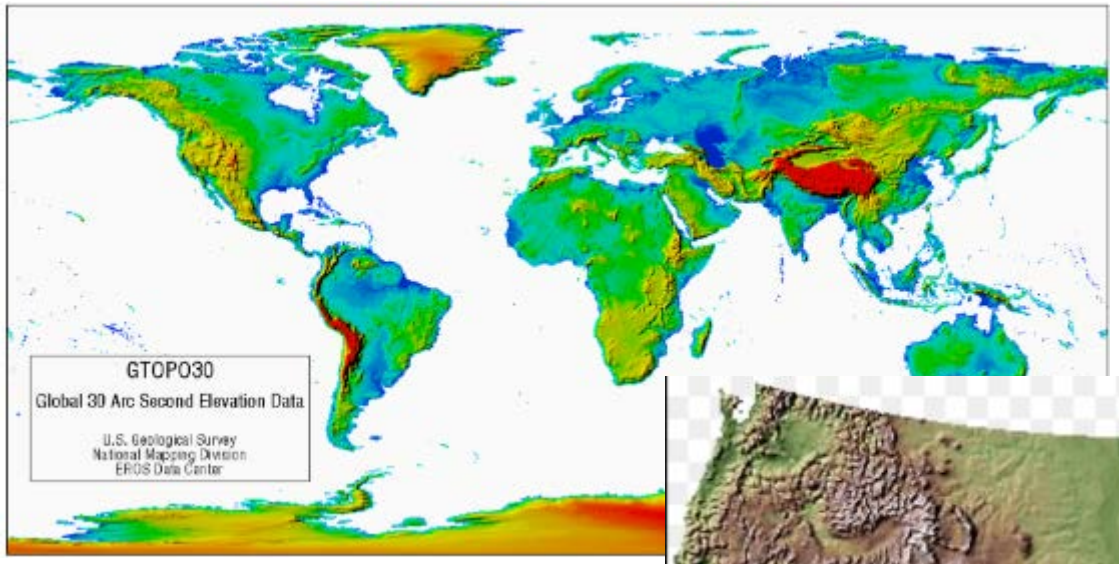
- Limitation:
  - One slope value for the entire catchment
  - One depression value impervious/previous surfaces
  - One infiltration parameter for all pervious area types
  - One roughness value for roofs, drive ways and streets

Enhanced 1D Approach

- Use the wealth of available digital data
- Split the catchment into independent hydrologic units
  - Roofs, House Perimeter, Lawn area, Driveway/Street
- Route the flow between the hydrologic features
- Use the digital terrain data to accurately represent
  - Depression storages
  - Represent streets as open channels
- Include the storm inlets configuration to enhance percentage capture and street ponding/attenuation



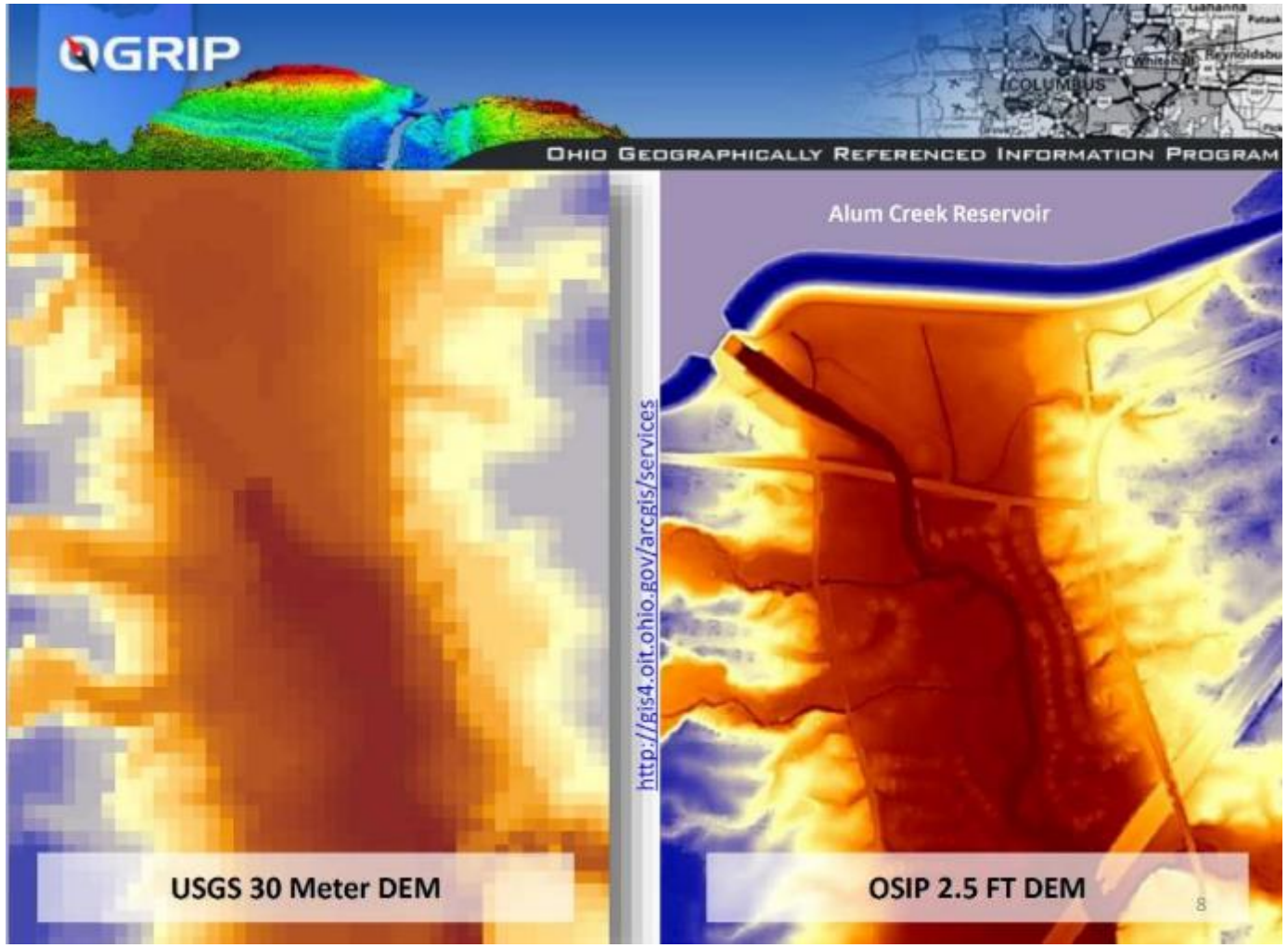
Data Sources



GTOPO30 for the world wide, It has a 30-arc second resolution, ~ 1KM

https://www.usgs.gov
National Elevation Dataset resolution, ~ 30m

Data at Finer Resolution



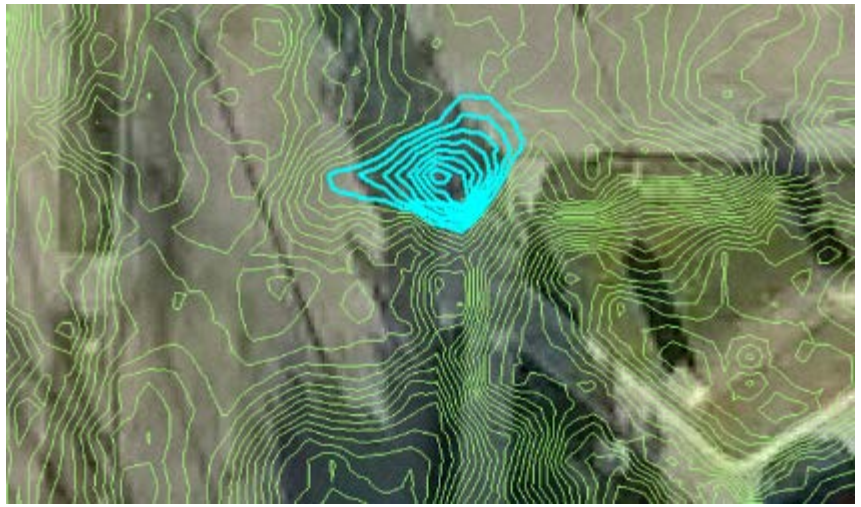
- High resolution model
- Improves planning quality
- More accurate and automated
- Enhances the flow prediction

Provides robust foundation for planning and managing stormwater improvements

GIS Data

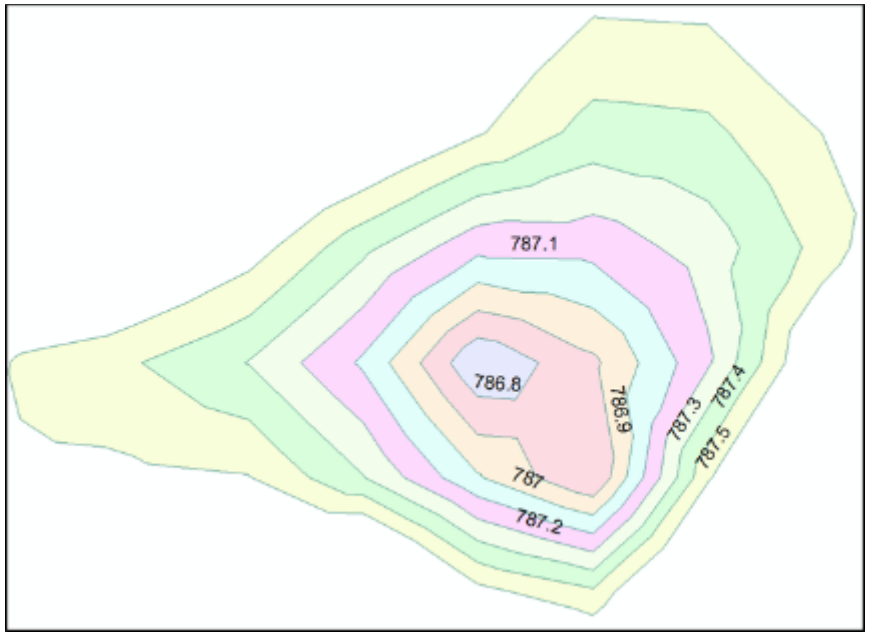
- Independent hydrologic features (subareas)
  - Roofs
  - Buffers
  - Lawn
  - Streets

Depression Storage Curves

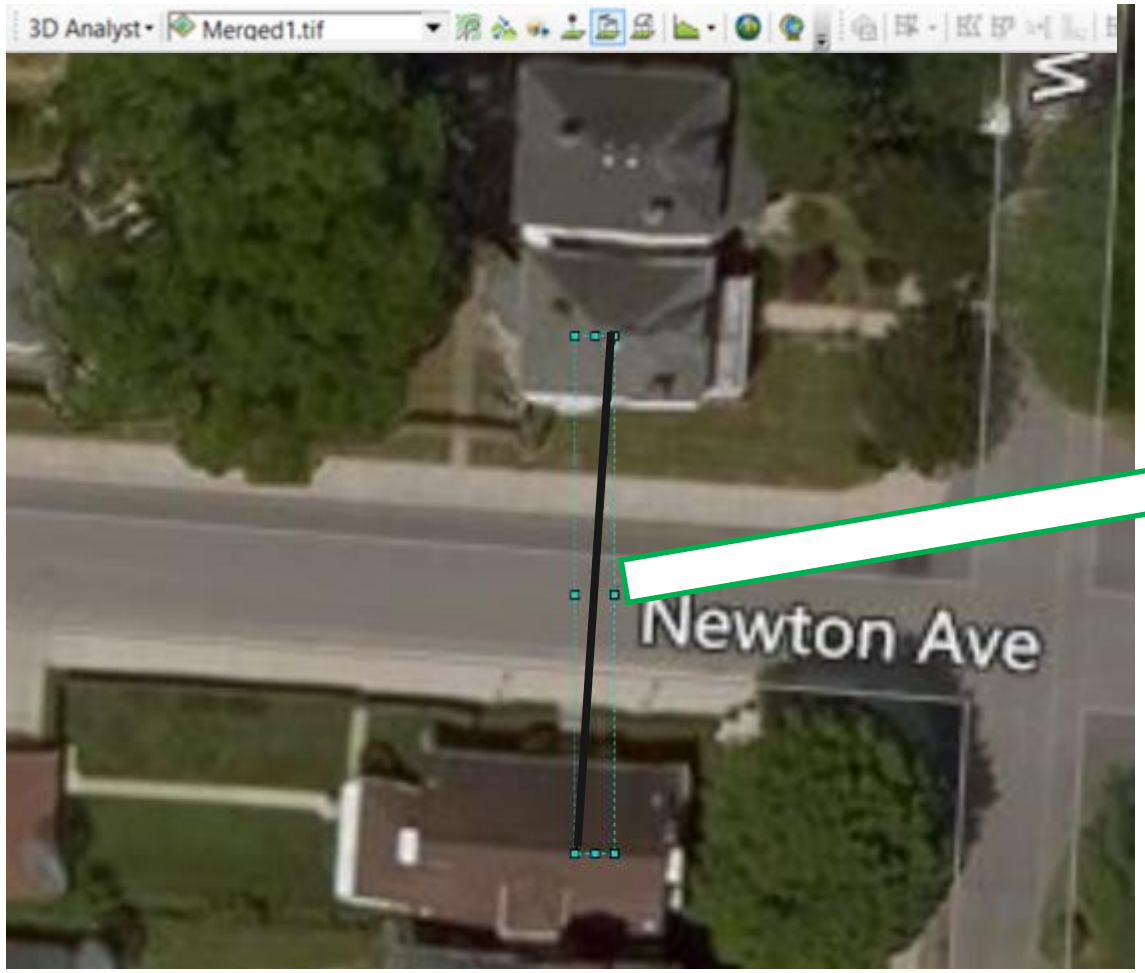


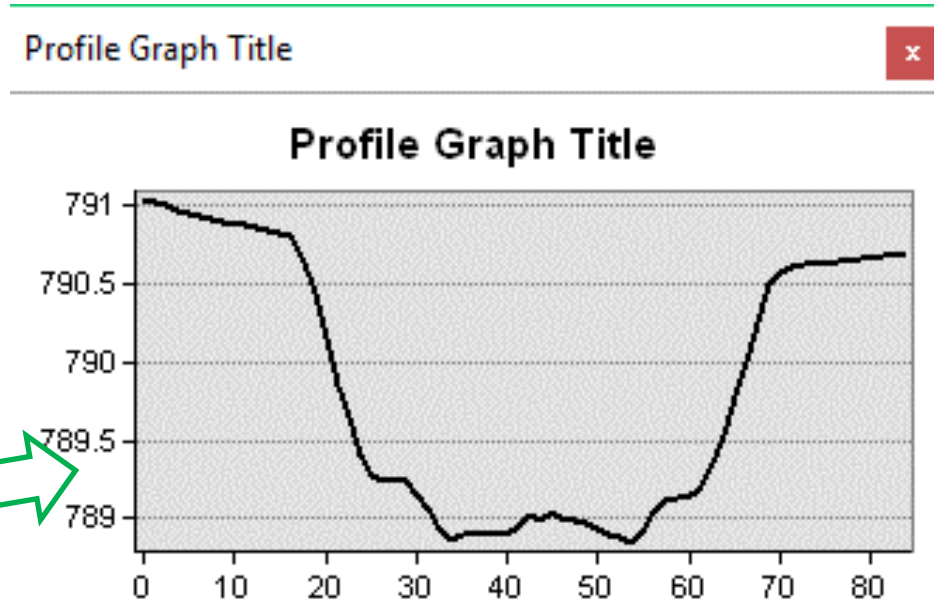
FID	Shape	Id	Elevation	area
0	Polygon	46699	786.8	1.7
2	Polygon	46719	786.9	10.2
1	Polygon	46719	787	18.6
4	Polygon	46720	787.1	28.8
3	Polygon	46720	787.2	43.4
5	Polygon	46720	787.3	61.8
6	Polygon	46720	787.4	87.1
7	Polygon	46741	787.5	126.6

Automate depth-storage curve generation



Street Open Channel Routing

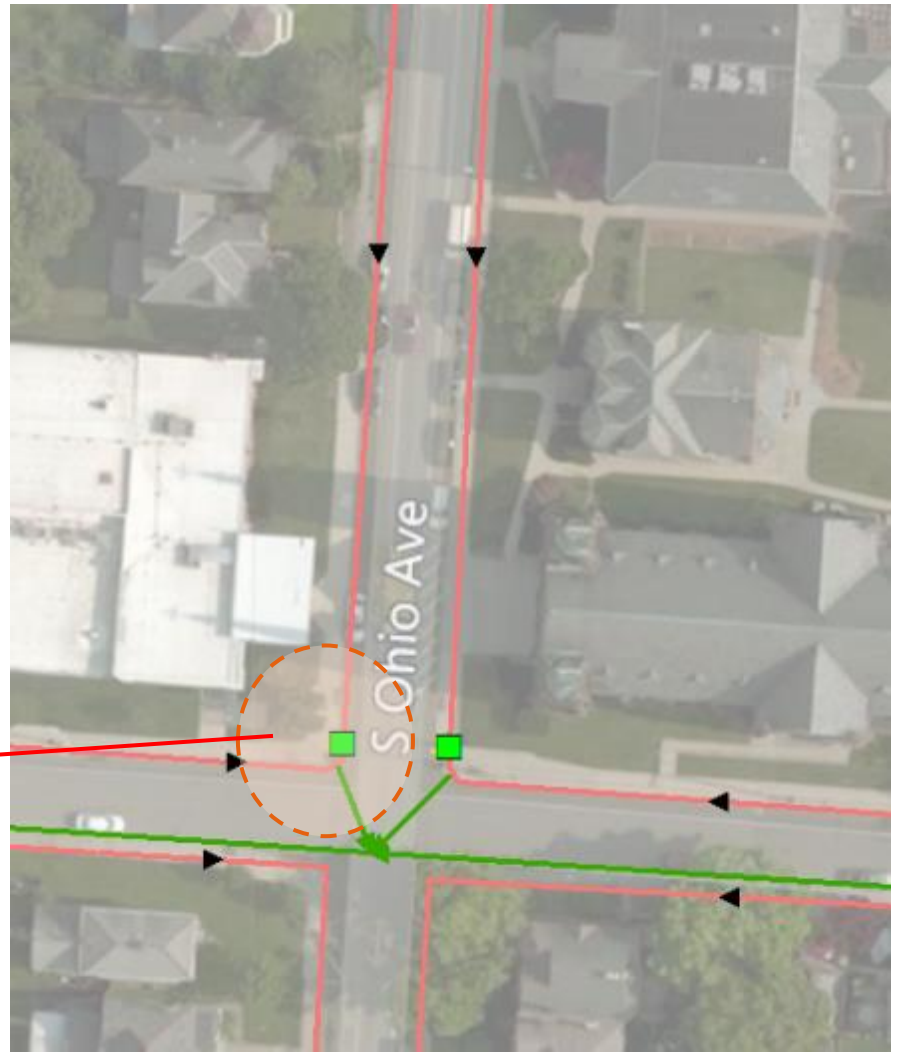




- LiDAR and ArcGIS 3D Analyst
- Street profile
- Both sides of street with weir connection

Storm Inlets

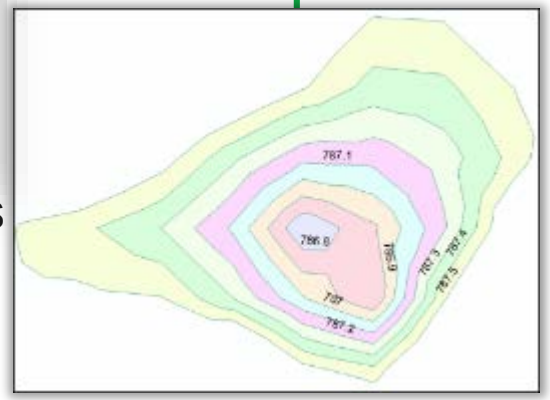
- Include storm inlets limitation from survey data or google maps
- Calibrate storm inlet effectiveness using street ponding information



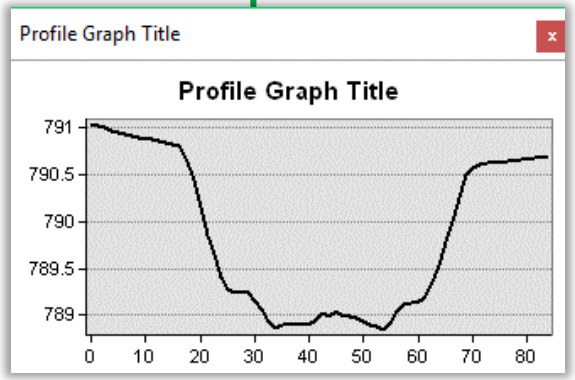
Summary of Model Construction Steps

Model Construction

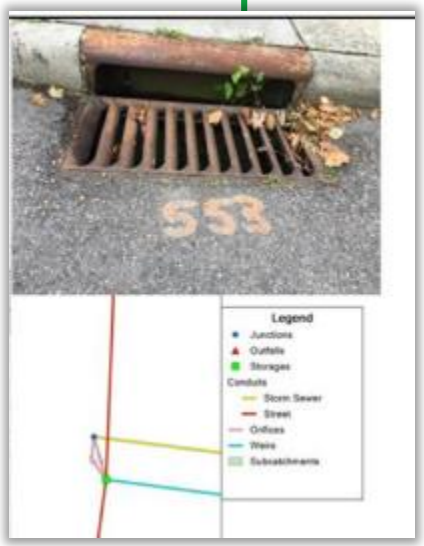
Hydrologic Components



Depression Storage

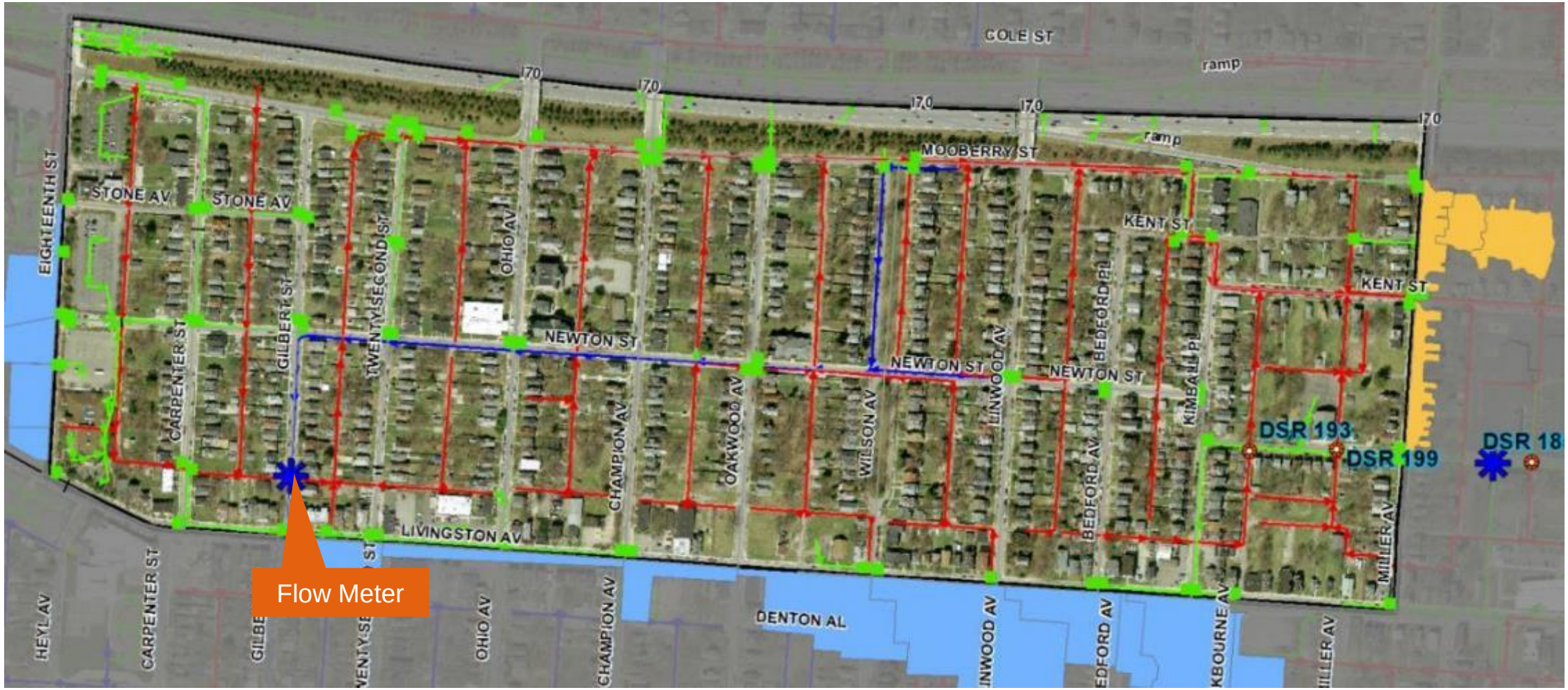


Street Channels

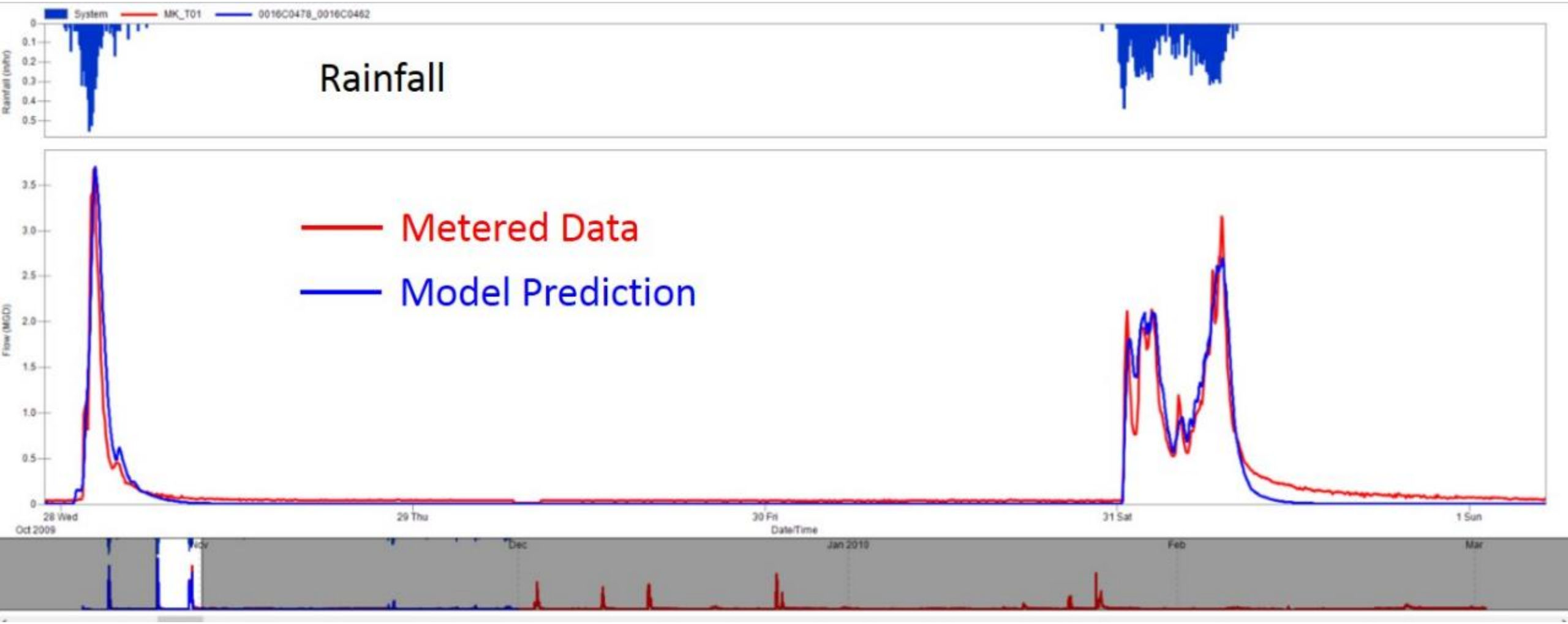


Storm Inlets

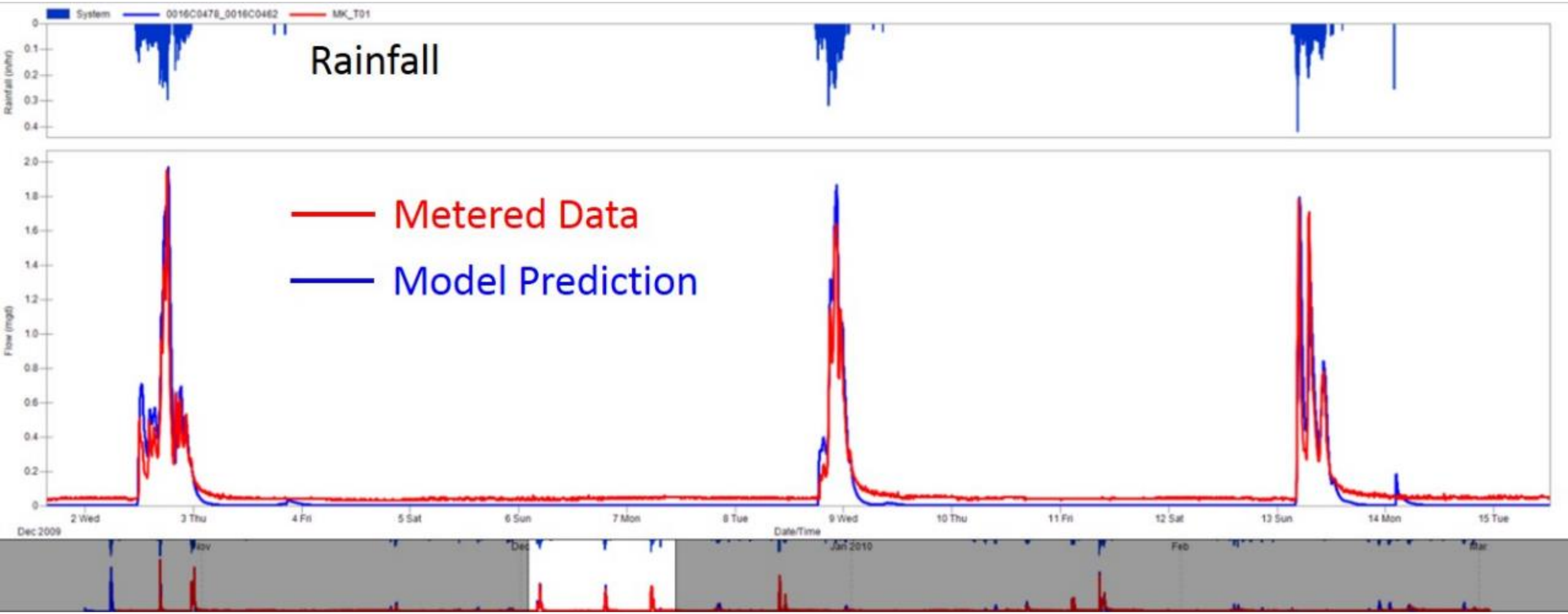
Flow Prediction Quality



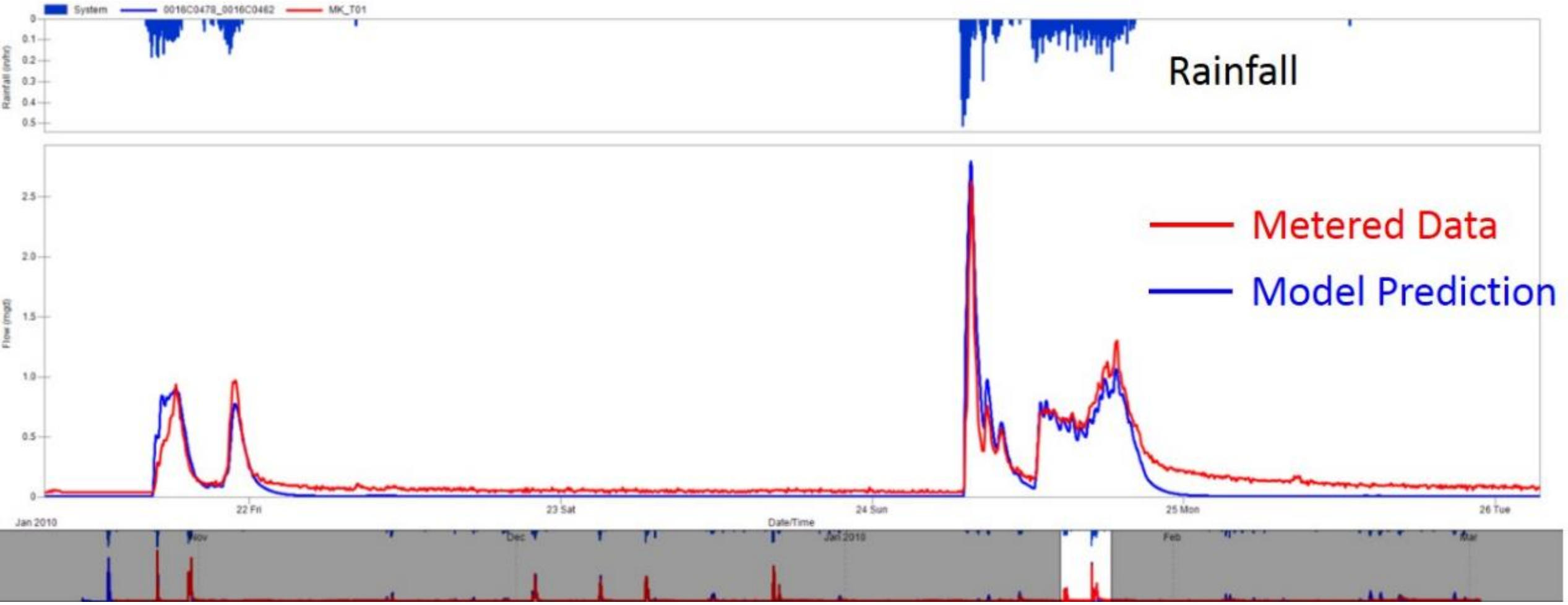
Model Validation – October 2009



Model Validation – December 2009



Model Validation – January 2010

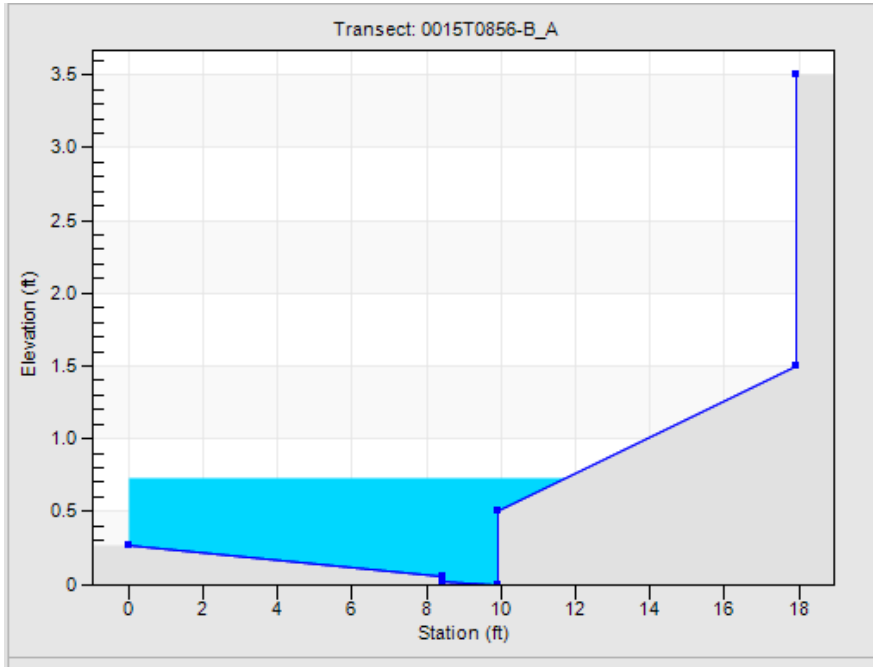


Completed Studies

Programs/Pilots since 2012

- ❑ Columbus Integrated Plan (SWMM)
- ❑ Columbus Blueprint Program (SWMM)
- ❑ Cincinnati (SWMM)
- ❑ Indianapolis (ICM)
- ❑ Buffalo (SWMM)
- ❑ DC Water (SWMM)
- ❑ Ft Wayne (SWMM)
- ❑ City of Westfield (ICM)
- ❑ City of Marysville (SWMM)
- ❑ York Region, Canada (ICM)
- ❑ Pittsburgh (SWMM)

Street Flows



Enhanced 1-D Limitation

- Fast, City wide, basin wide

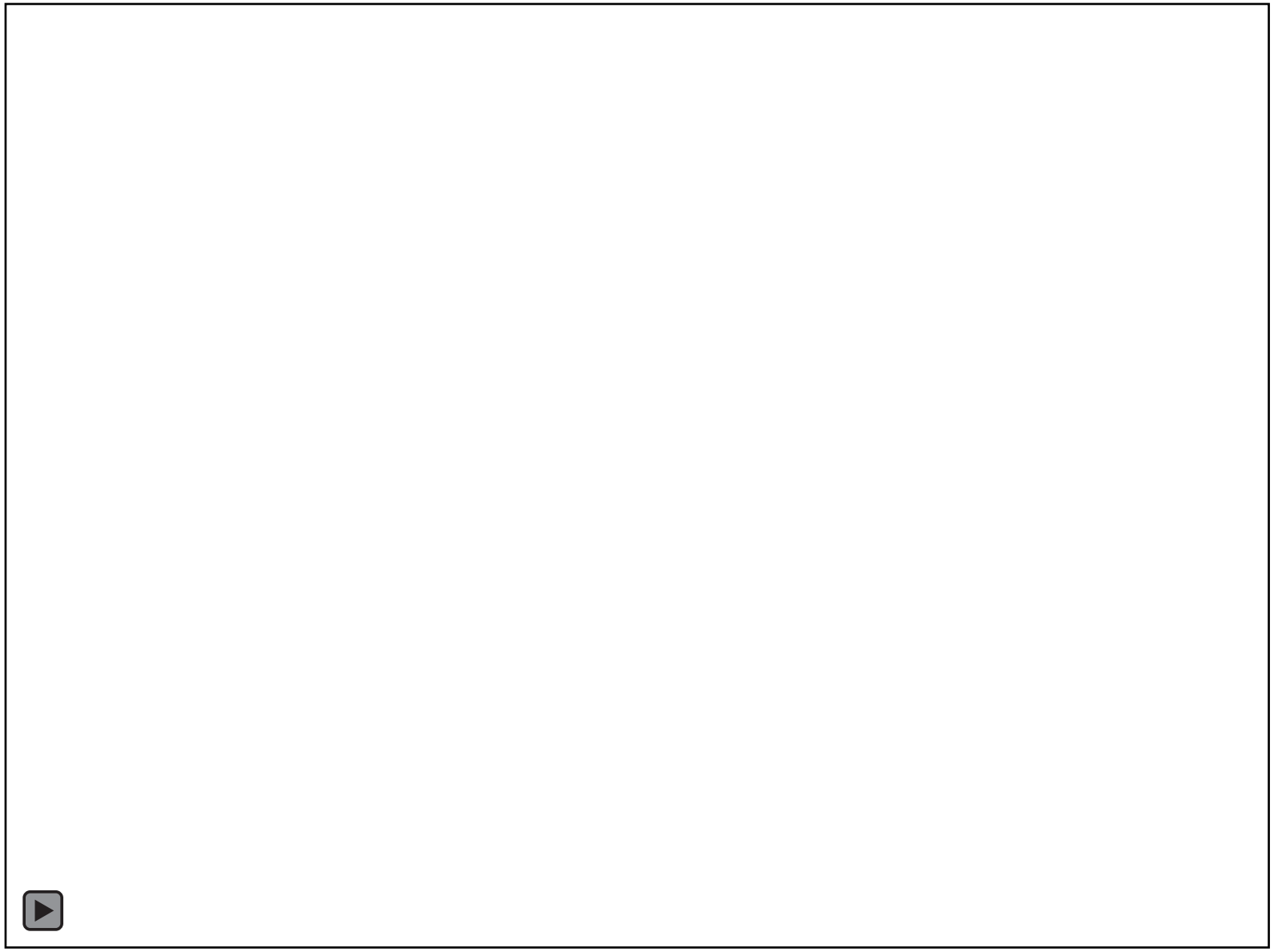
Limitations

- Limited number of street cross sections in 1-D
- Weirs to connect overflow from one side to another
- Unexpected hidden routing configuration
- 2D section still needed for surface routing

2D Modeling Approach

- Divide the urban area into small cells
- Topology decides how flow is routed from one cell to another
- Different resolution for street, lawn, and around the house
- Take the houses out

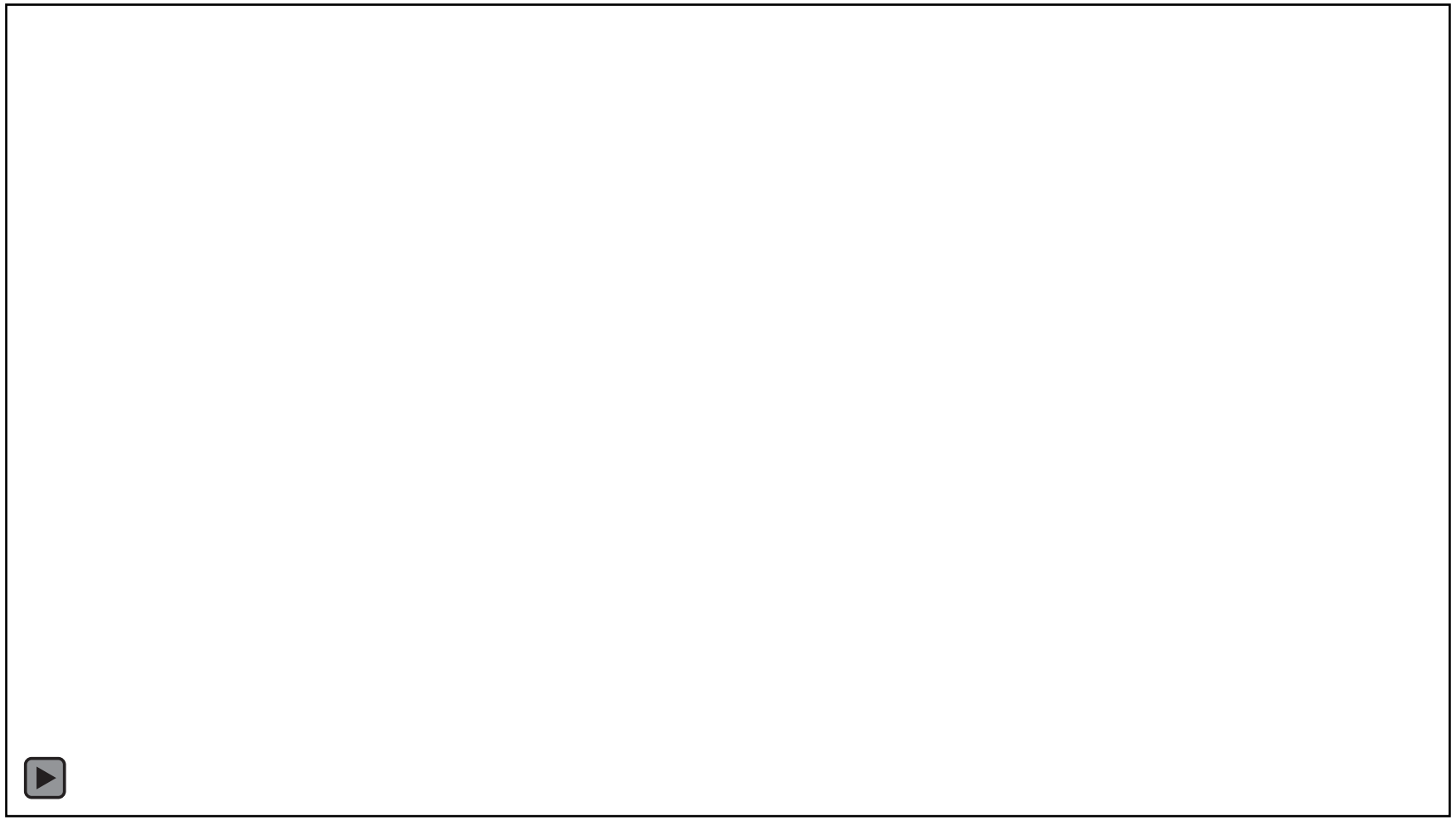
Example: 2-D Benefit Over 1-D Approach



Depression Analysis

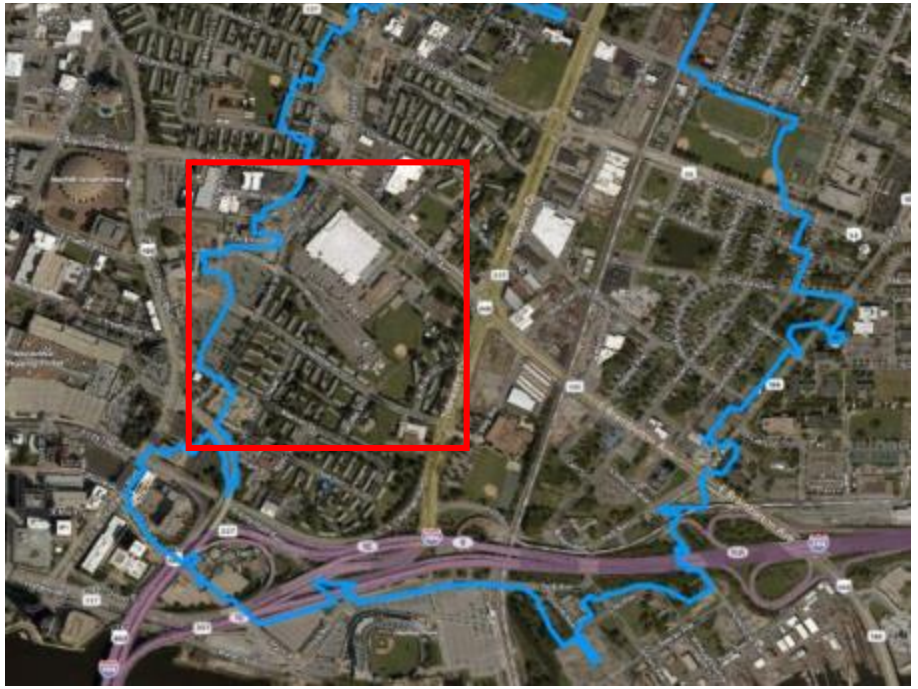
ArcGIS Sink Analysis applied to the Digital Terrain Data

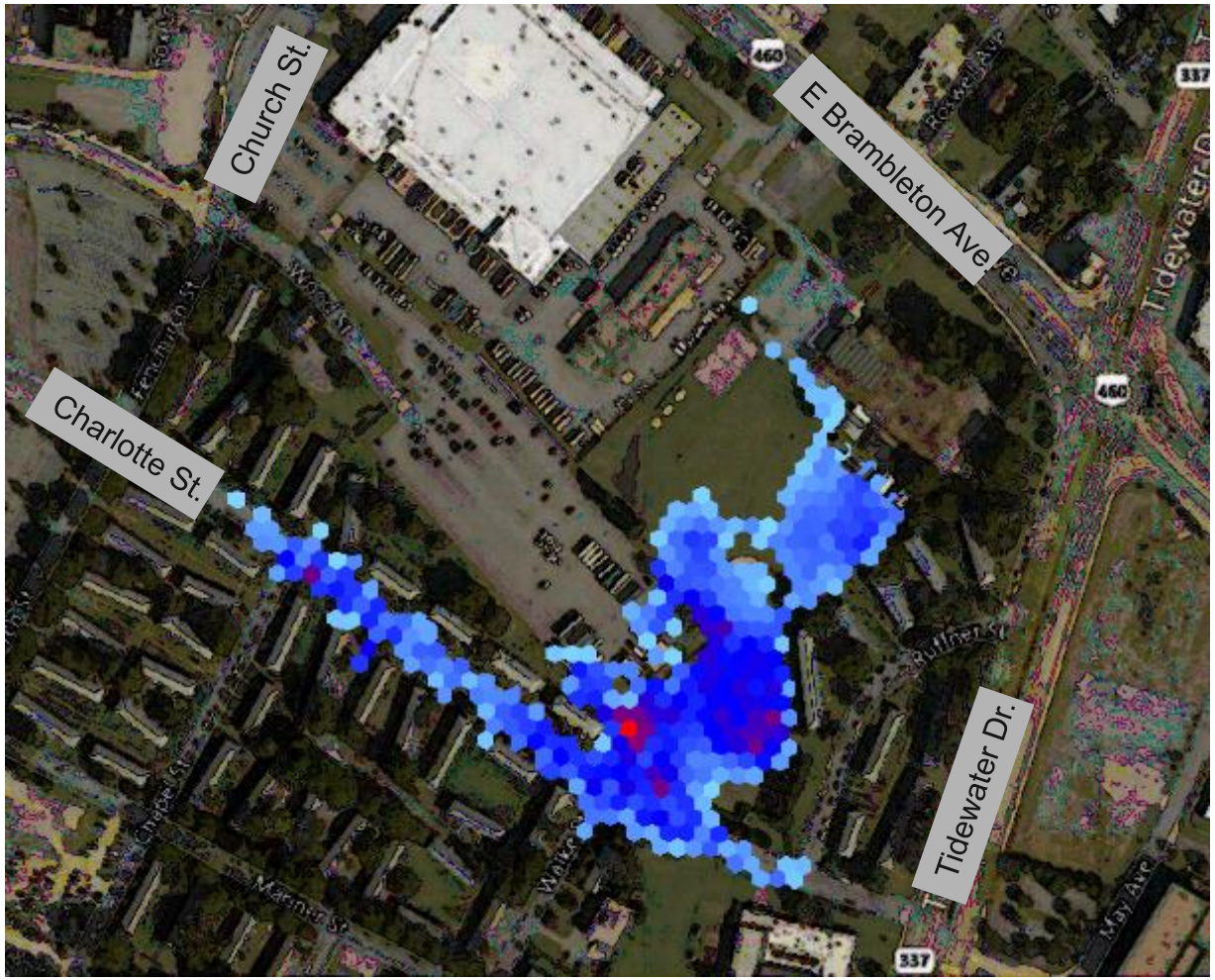
2-D Videos



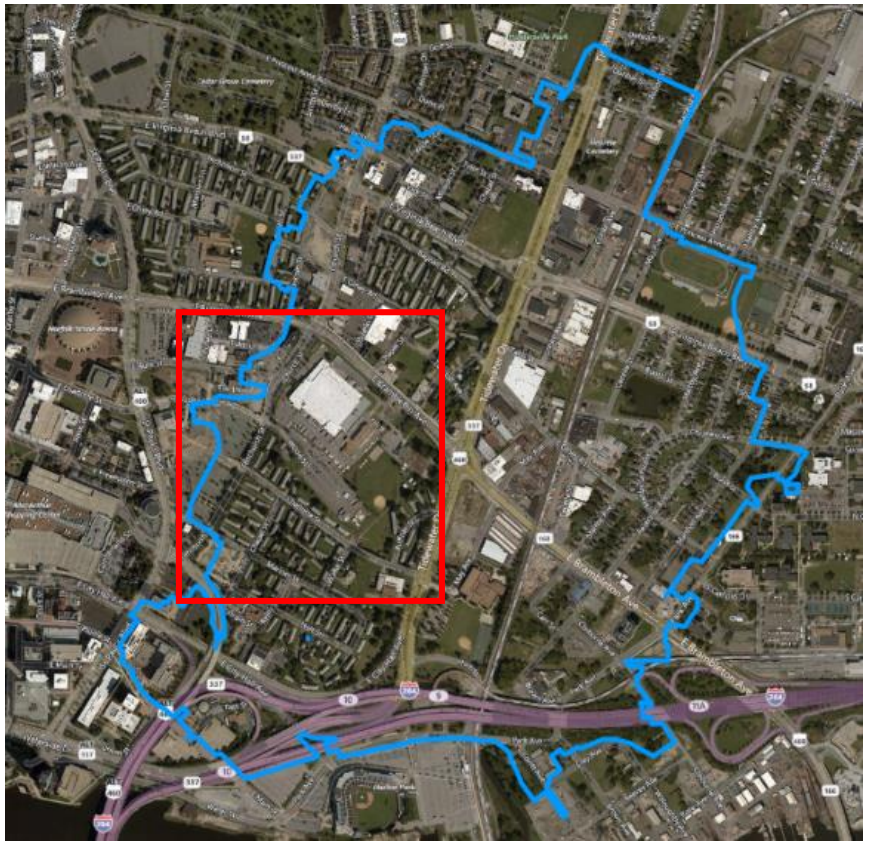
Central Residential District – High Tide

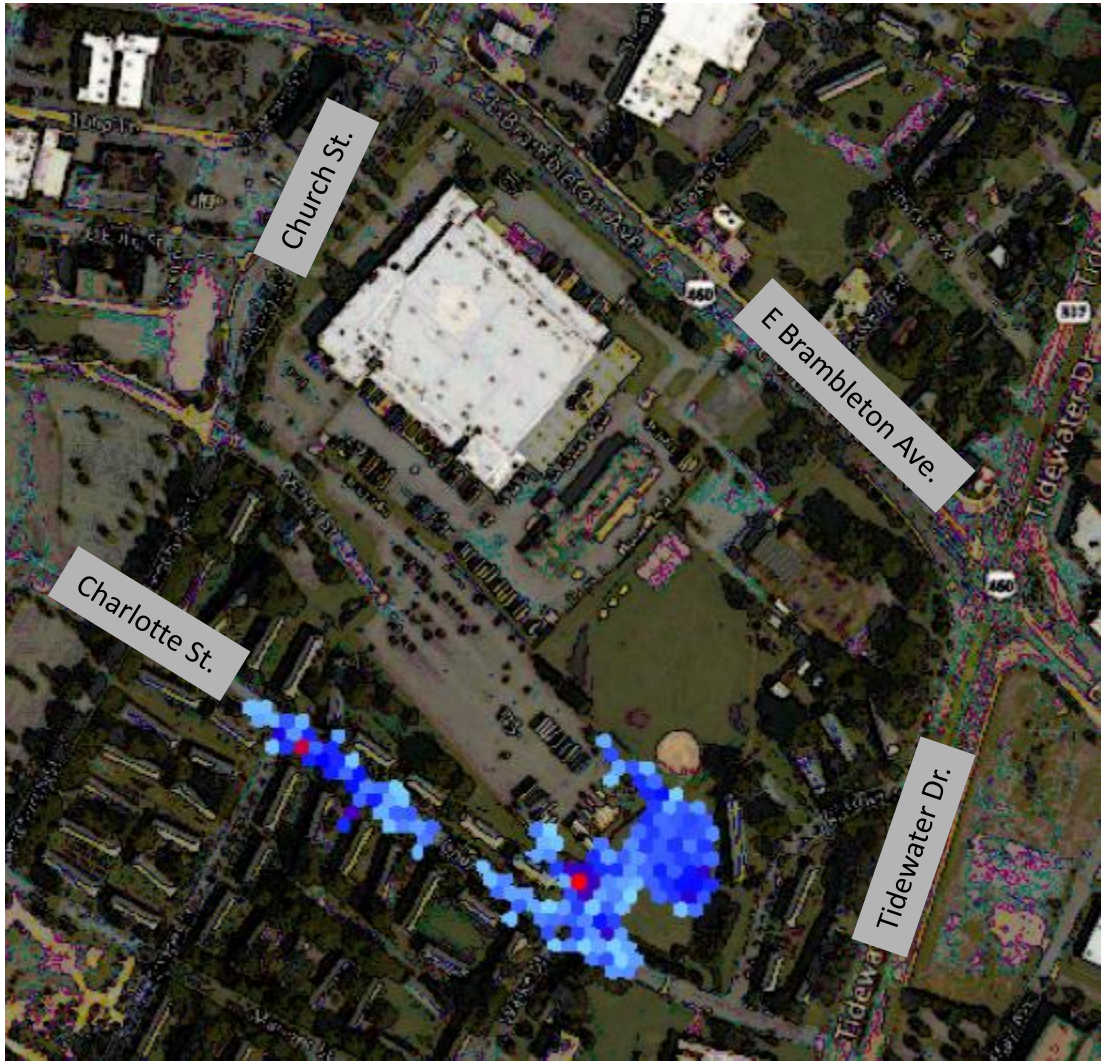
- Irene historical Storm
- Existing Condition
- 2D Modeling Analysis





Central Residential District – Free Outfall

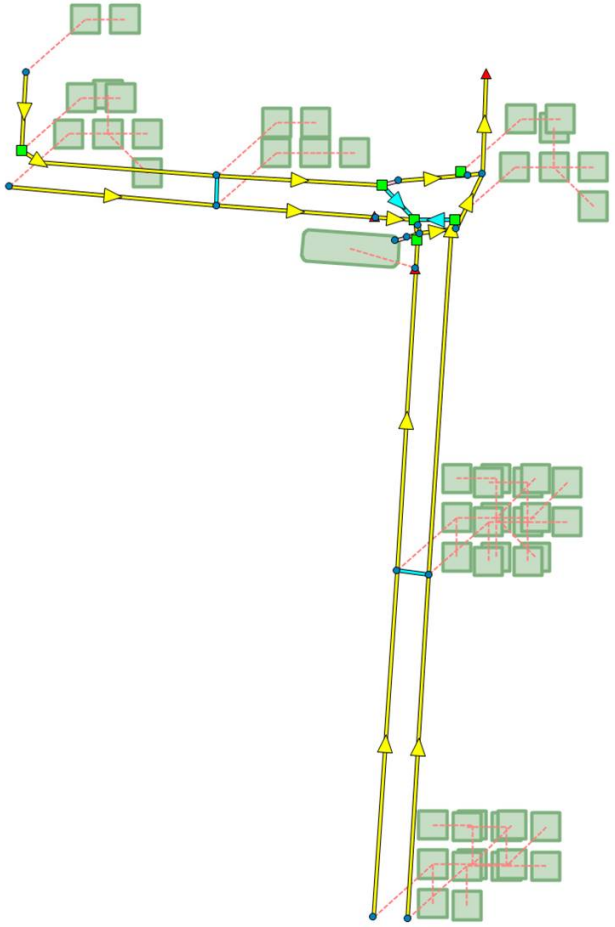




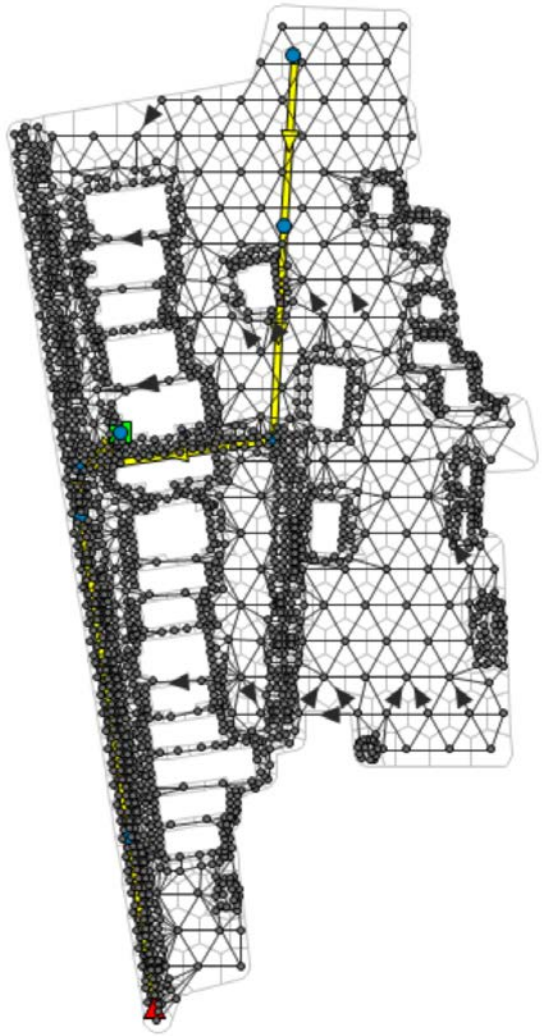
Limitations of 2D

- Large model size
- Slow simulation time
  - Project schedule, machine time, engineer time, etc.
  - Engineering decision in the resolution level
- Cannot do 2D with complicated configuration, like on highways

Simulation Time for 1-yr

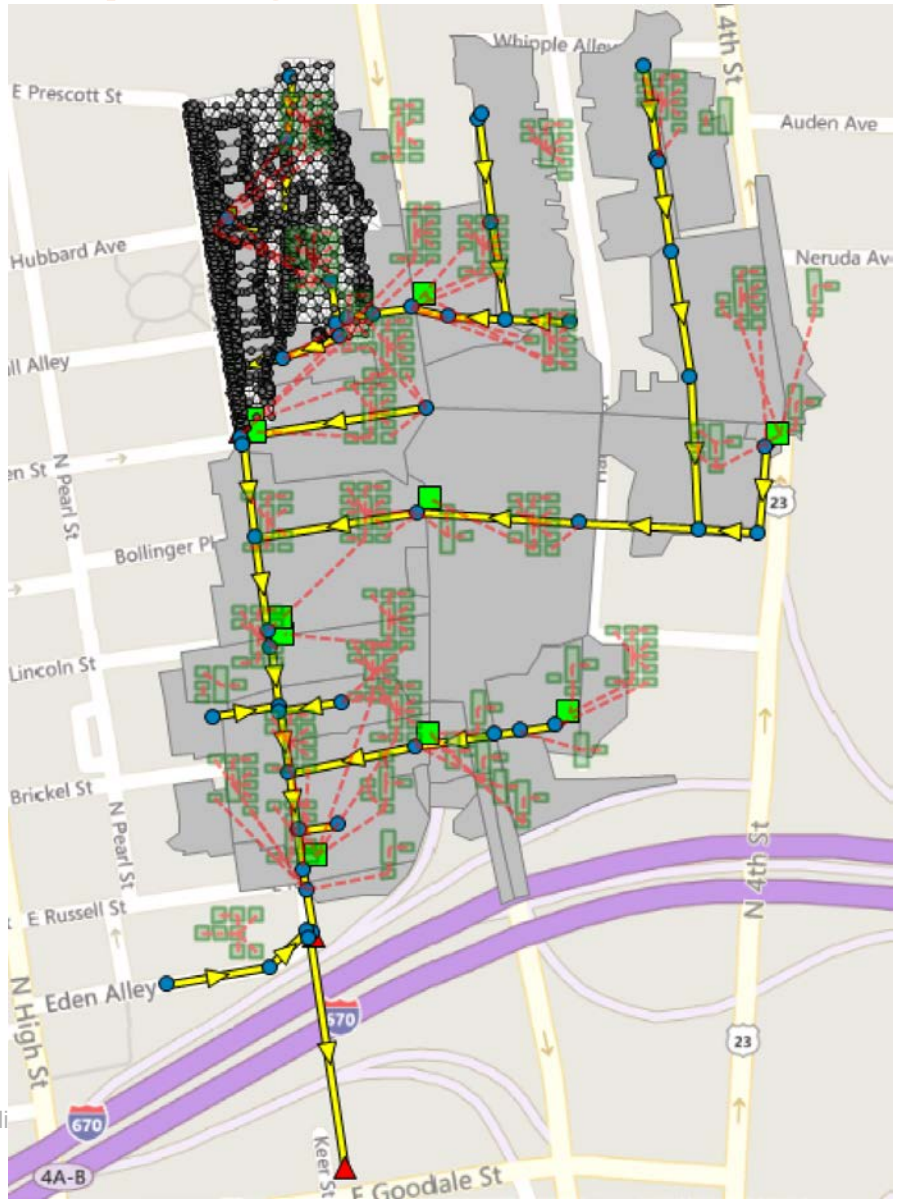


A few minutes



Hours

Coupling 1D with 2D



- Define 2-D boundary as runoff boundary
- Water can flow in and out from the 2-D zone

Conclusions

- Enhanced 1-D approach provided reliable flow prediction at good resolution
- Applicable for large scale studies
- 2-D model provides a better understanding of surface flow routing at critical locations
- Coupling 1-D and 2-D modeling approaches would provide a more accurate platform for educated GI planning in urban condition

Thank you!

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