Effects of input DEM data spatial resolution on Upstream Flood modeling result – A case study in Willamette river downtown Portland

By

Hue Duong

GEOG 593 – Fall 2015

Digital Terrain Analysis

Photo: Anh Duc Do

Contents:

Introduction:

- Upstream flood in downtown Portland:
  - In 1996 flood depth in Willamette River in Portland: 28.6 ft (Taylor, 1996).

Introduction:

Vanport Flood – North Portland 1948

1964 Flood

At Hawthorne Bridge

Introduction:

- Effect of climate change in Willamette River basin:
  - With warmer oceans and more available moisture in the atmosphere, storm events could increase in intensity, resulting in more flooding in all rivers in the Basin.
  - As snow melts earlier in the spring, stream flows will peak earlier but at lower levels than typical flows in recent years, depending on the geology of the particular stream reach.
- (From: *Preparing for Climate Change in the Upper Willamette River Basin of Western Oregon*, Doppelt et.al. 2009)

Introduction:

- Flood modeling is essential for better flood mitigation measure in the future.

Introduction:

- Flood simulation results relied on:
  - Choosing relevant model,
  - Using relevant input data: elevation data, geometric data of river network, and hydrologic data,
  - Among others.

Research questions:

- How to extract river network geometric data from digital elevation data to run HEC-RAS model?

- How do the simulated upstream flood in Willamette River in Portland, that resulted from HEC-RAS model, changes when increase input DEM data spatial resolution from 1m to 10m?

Why HEC-RAS?

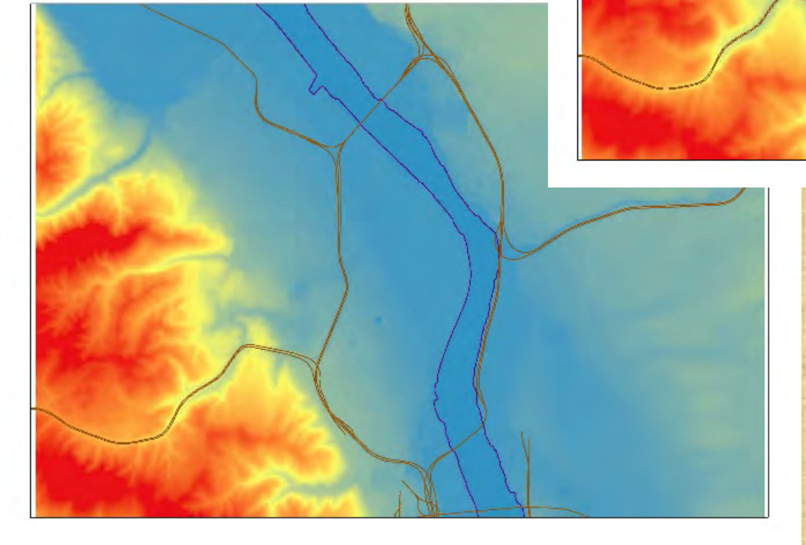
- Developed by The Hydrologic Engineering Center (HEC), an organization within the Institute for Water Resources of the U.S. Army Corps of Engineers.
- Allow to perform steady flow, unsteady flow, and sediment transportation.
- Open sources.
- Used widely in the US.

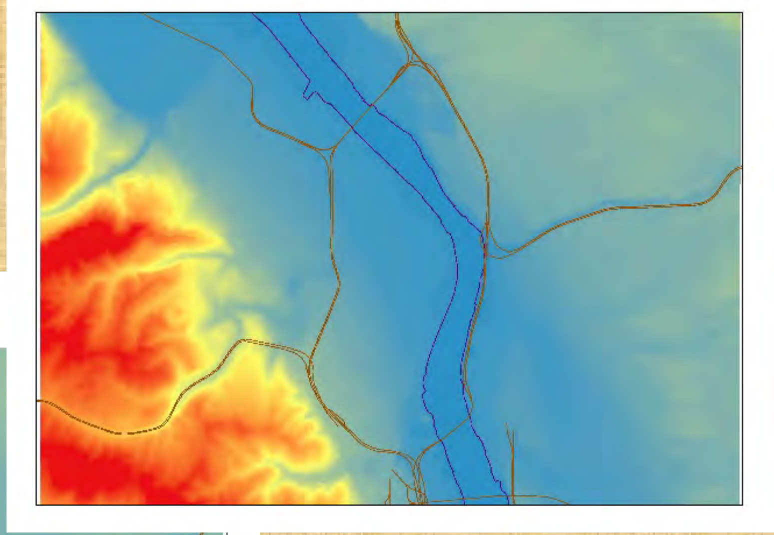
Methods

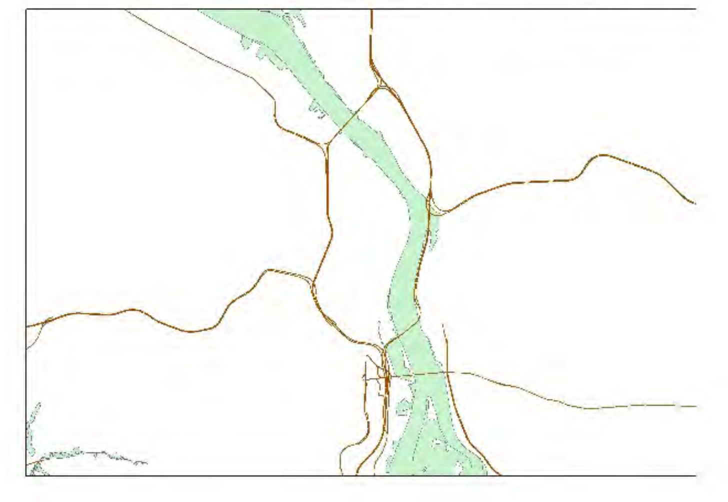
- Data preparation – using Spatial Analysis and 3D Analysis extensions in ArcMap.
- Geometric data extraction – using Geo-RAS tools in ArcMap.
- Importing extracted geometric data to HEC-RAS to run the flood models.
- Comparing the simulated results from 1m and 10m DEM.
- Comparing the simulated flood extent with the FEMA flood map.

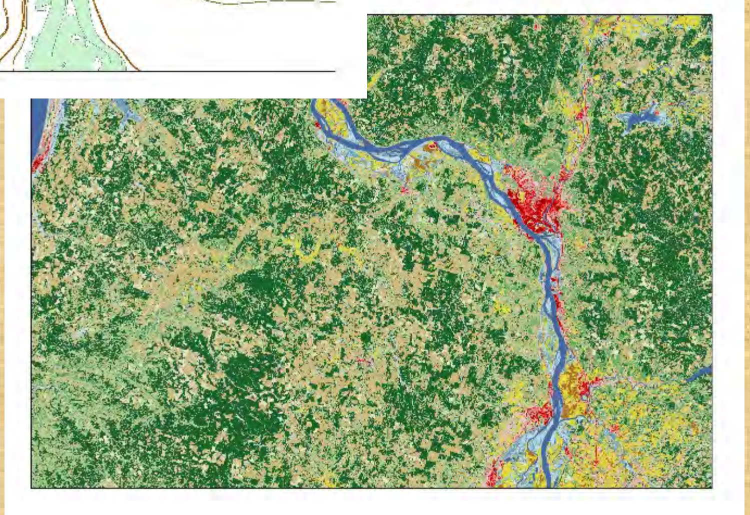
Data sources:

Data used	Data sources
1m DEM data	ArcGIS server of Department of Geography http://atlas.geog.pdx.edu/arcgis/rest/services
10m DEM data	I:\ drive
FEMA flood map	I:\ drive
Roads	I:\ drive
NLCD 2011 Land Cover data	Multi-Resolution Land Characteristics Consortium http://www.mrlc.gov/nlcd11_data.php
Daily average discharge data (USGS 14211720 Willamette River at Portland stream gauge)	US Geological Survey http://waterdata.usgs.gov/usa/nwis/uv?site_no=14211720


1m DEM


10m DEM


Roads and FEMA Flood Maps


Cover

Data Used

Daily discharge, cubic feet per second -- statistics for Dec 4 based on 42 years of record						
Daily Discharge	Min (1977)	25th percentile	Median	Mean	75th percentile	Max (1999)
(ft3/s)	8440	25900	64900	71100	112000	160000

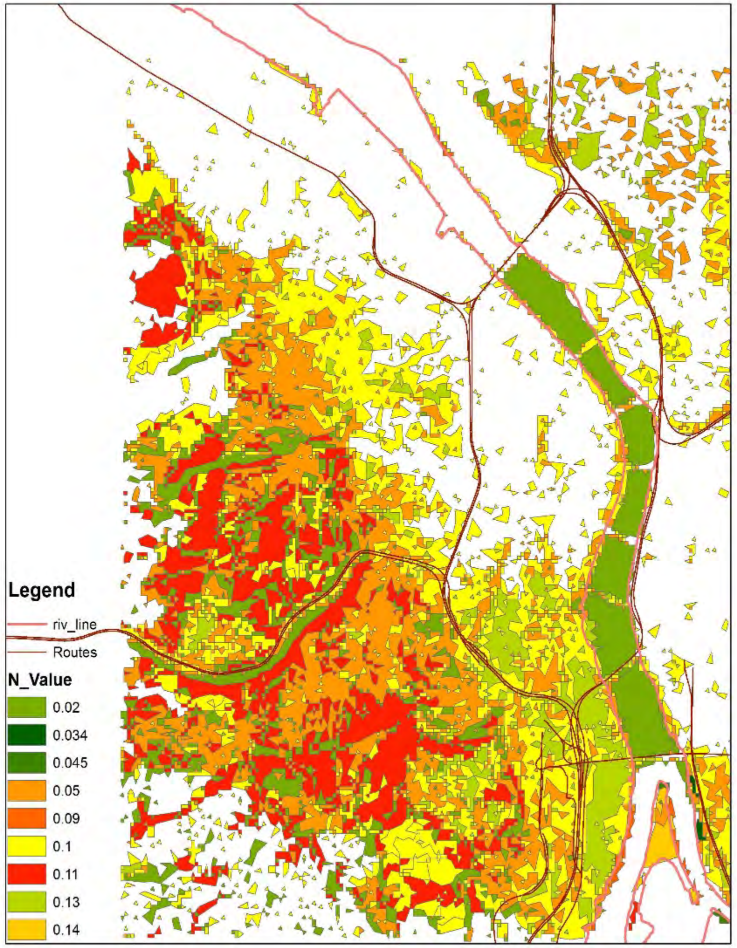
Data preparation:

- Clipping DEMs to reduce data volume.
- Converting 1m and 10m DEMs to TINs.
- Assigning Manning's friction coefficient for each pixel based on land cover types, then converting the output raster to polygon as requirements of HEC-RAS.

Table 1 Manning coefficients for various categories of land cover (adapted from Mattocks and Forbes, 2008).

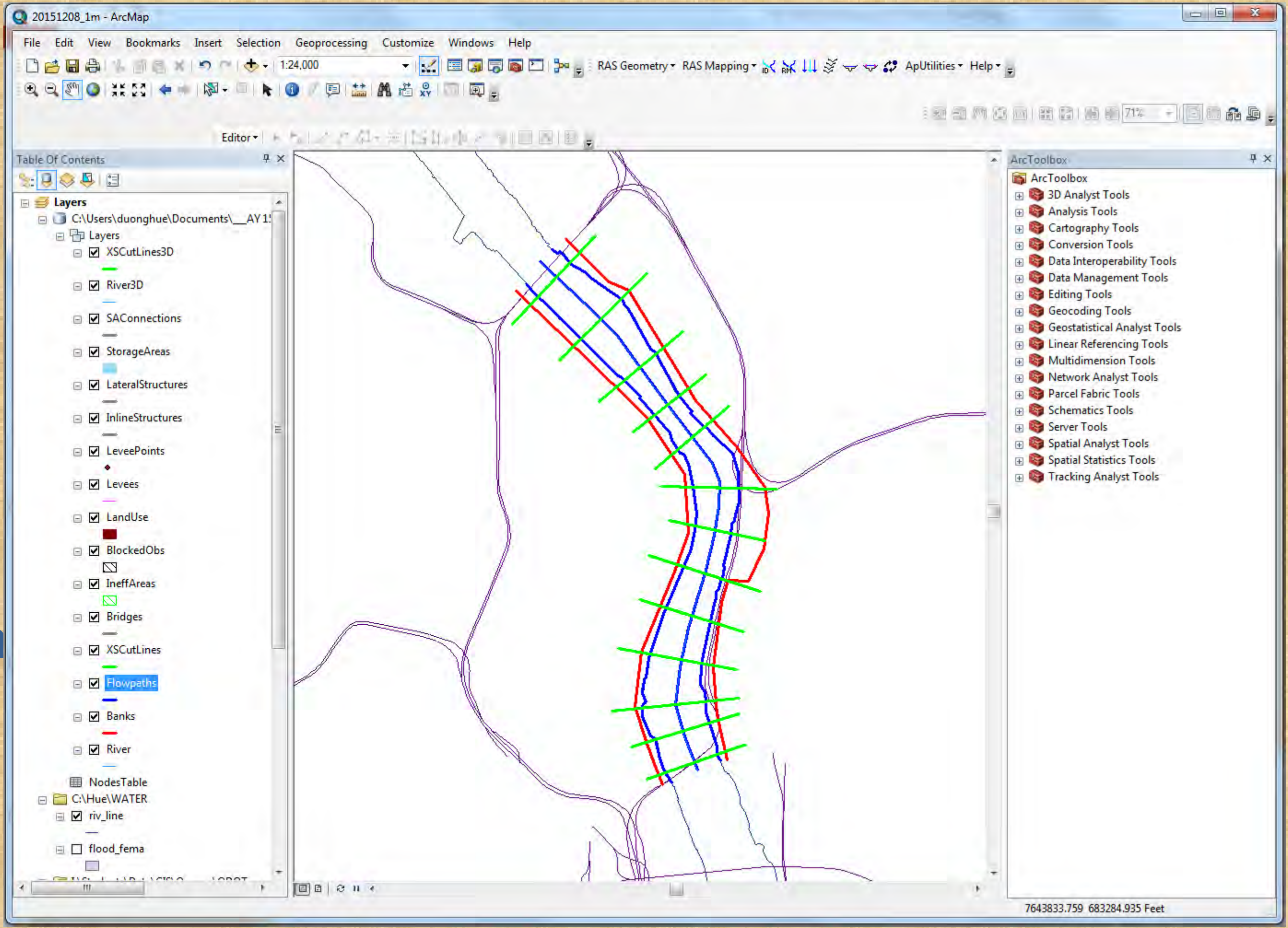
NLCD Class number	NLCD Class name	Manning coefficient
11	Open water	0.020
12	Perennial ice/Snow	0.010
21	Developed open space	0.020
22	Developed low intensity	0.050
23	Developed medium intensity	0.100
24	Developed high intensity	0.130
31	Barren land (Rock/Sand/Clay)	0.090
32	Unconsolidated shore	0.040
41	Deciduous forest	0.100
42	Evergreen forest	0.110
43	Mixed forest	0.100
51	Dwarf scrub	0.040
52	Shrub/Scrub	0.050
71	Grassland/Herbaceous	0.034
72	Sedge/Herbaceous	0.030
73	Lichens	0.027
74	Moss	0.025
81	Pasture/Hay	0.033
82	Cultivated crops	0.037
90	Woody wetlands	0.140
91	Palustrine forested wetland	0.100
92	Palustrine scrub/Shrub wetland	0.048
93	Estuarine forested wetland	0.100
94	Estuarine scrub/Shrub wetland	0.048
95	Emergent herbaceous wetlands	0.045
96	Palustrine emergent wetland (Persistent)	0.045
97	Estuarine emergent wetland	0.045
98	Palustrine aquatic bed	0.015
99	Estuarine aquatic bed	0.015

Land Cover data with Assigned Manning's Coefficient

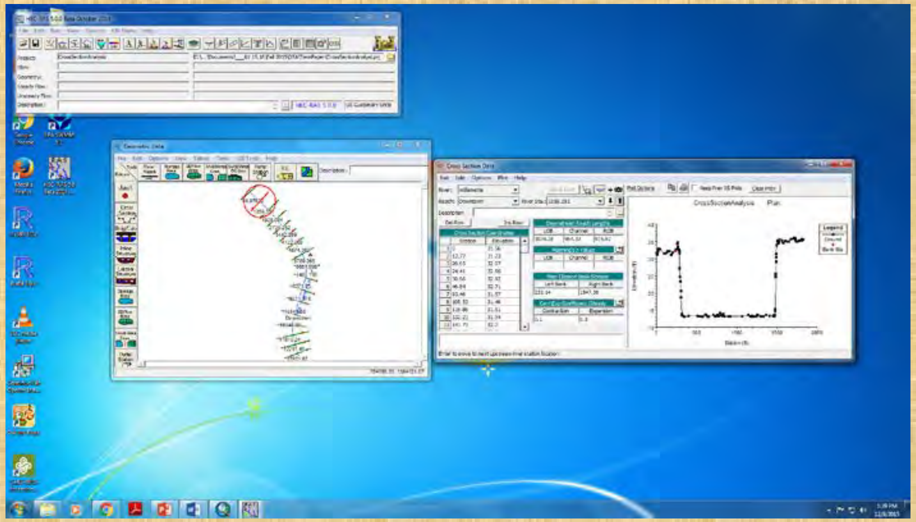


Geometric data extraction – Using Geo-RAS tools in ArcMap

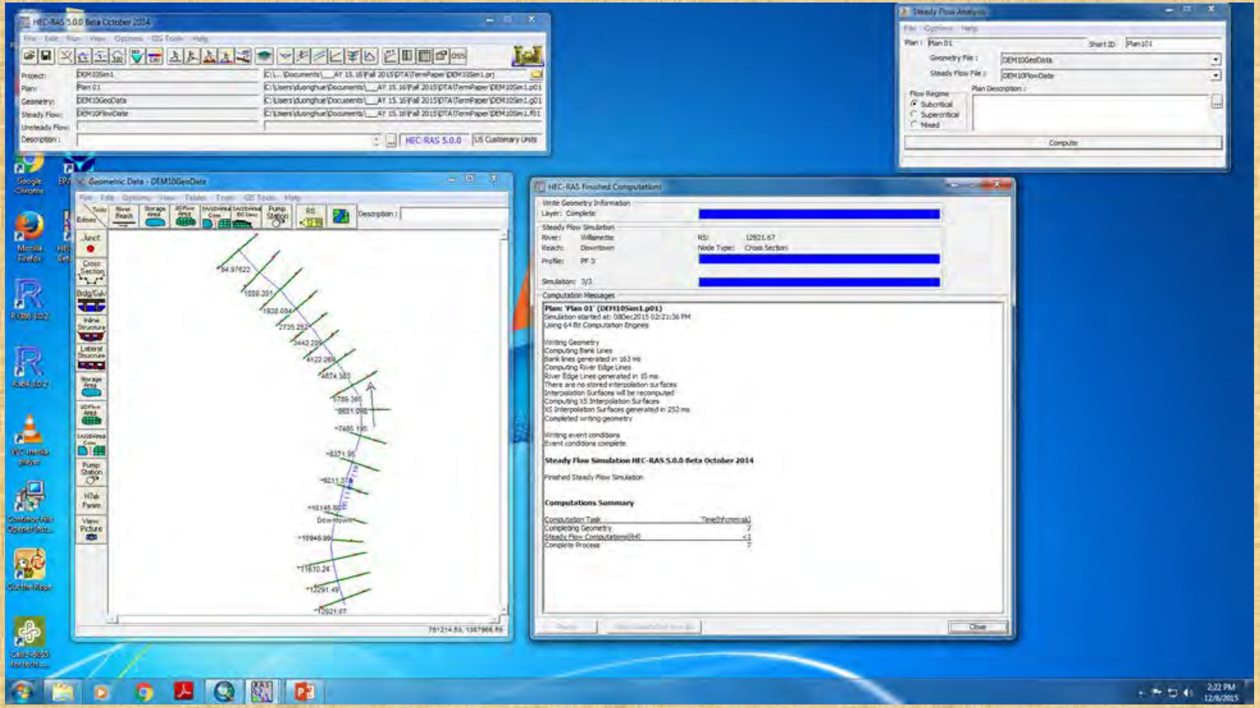
- **River centerlines**, shapefile and .dbf table.
- **River bank**, shapefile and .dbf table.
- **Flow paths**, shapefile and .dbf table.
- **2D cross-section**, shapefile.
- **3D cross-section**, shapefile and .dbf table.
- **Manning's friction coefficient** at each cross-section, .dbf table.

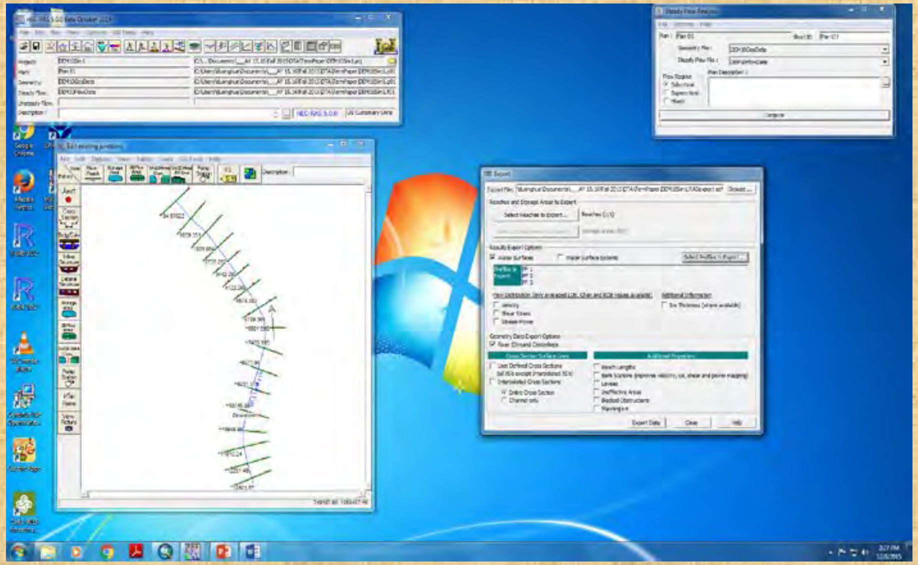


Modeling



Imported Geometric Data in HEC-RAS

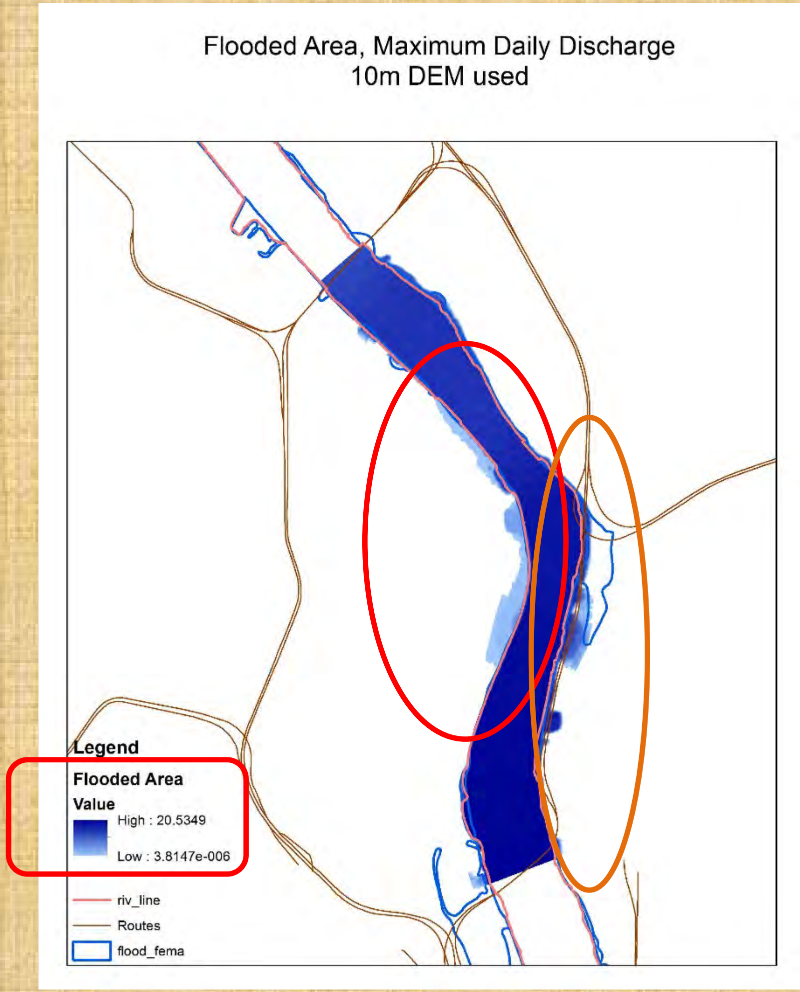


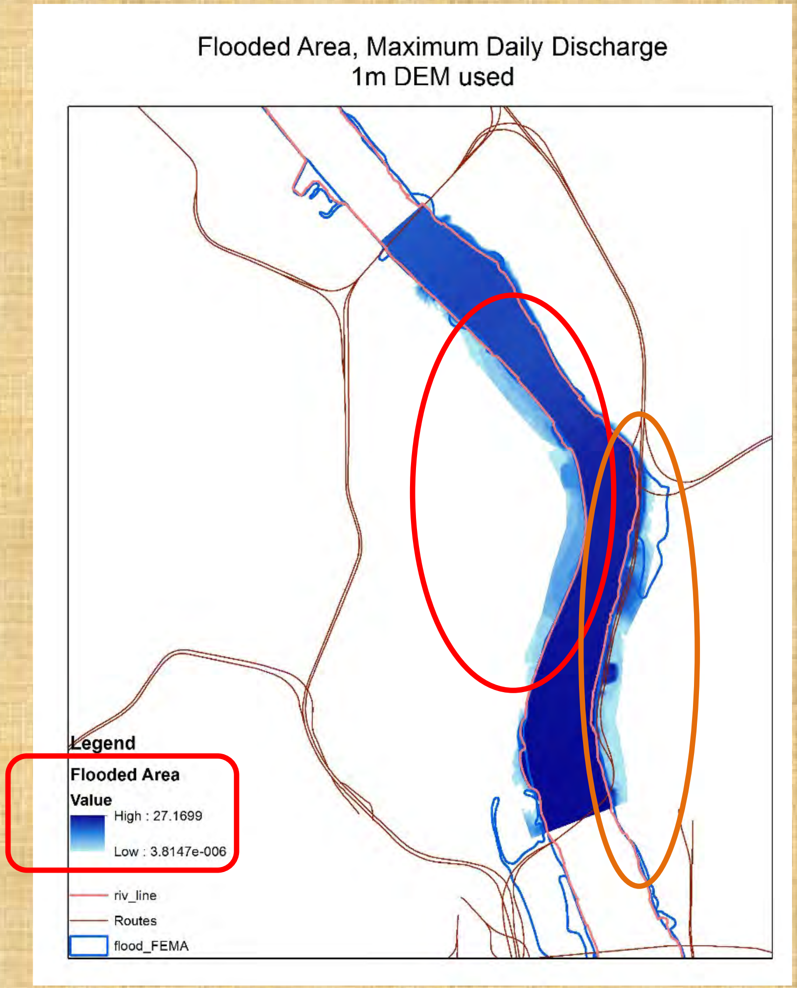


Exported Geometric Data to GIS format for water surface generation.

Upstream Flood at Maximum Daily Discharge

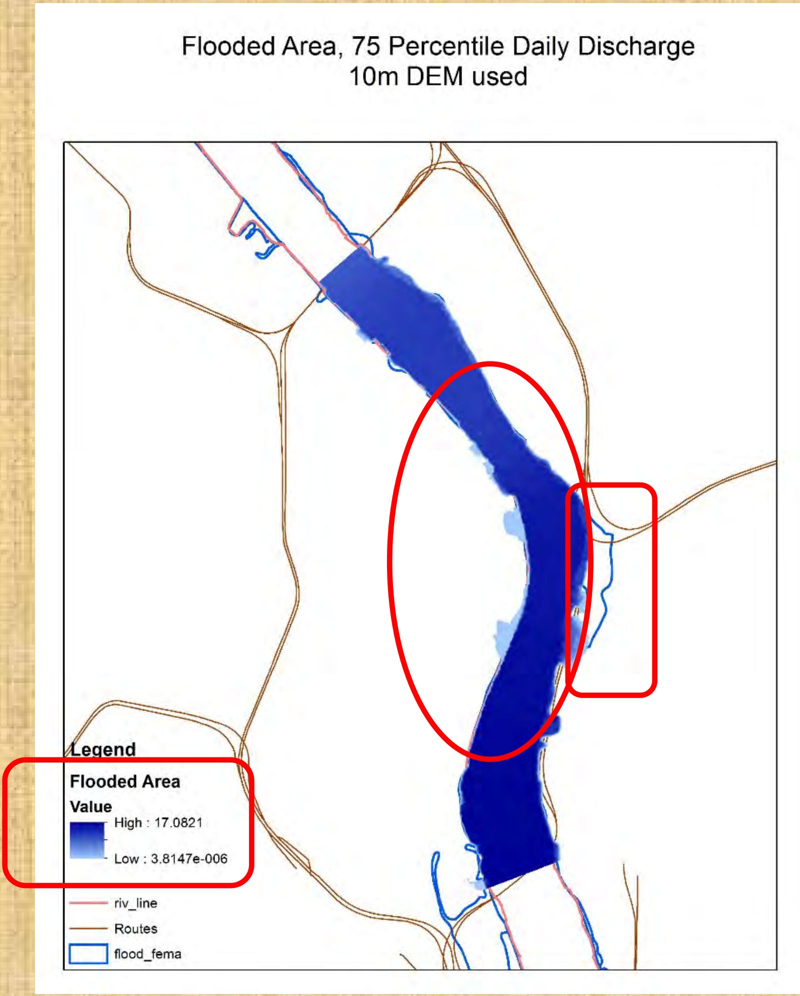
- When increasing spatial resolution of input DEM from 10m to 1m:
  - Highest flood depth increases **6.6 inches**.
  - The flooded areas are broaden in **west** and **southeast** of the river segment.
- The simulated flooded extent does not cover the FEMA flood area in the **middle east** of river segment.

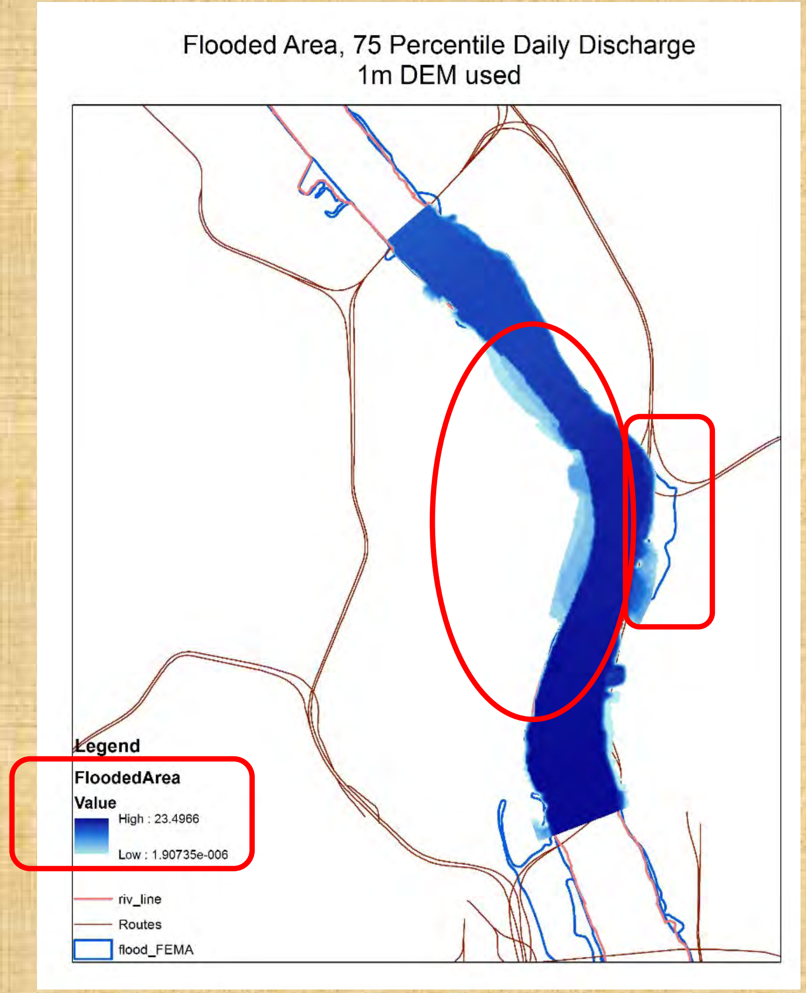


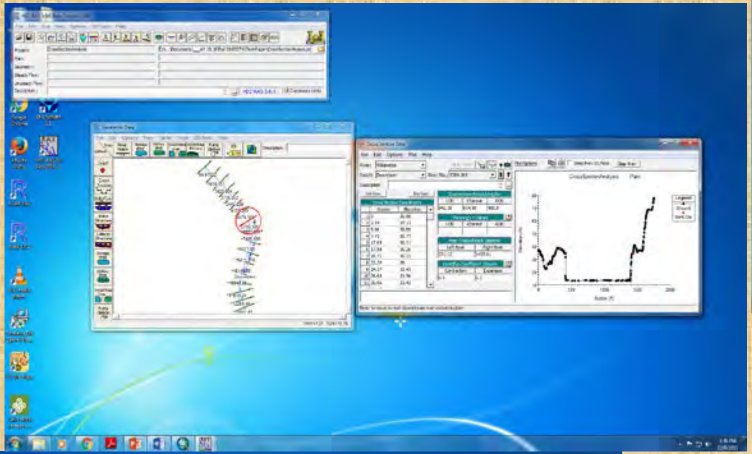


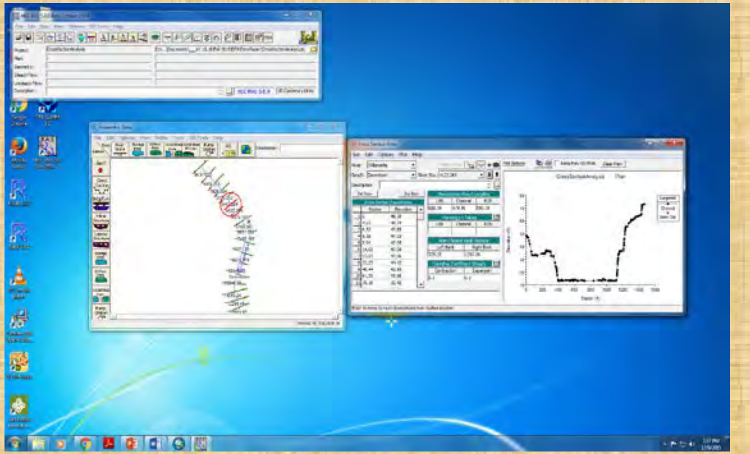
Upstream Flood at 75 Percentile Daily Discharge

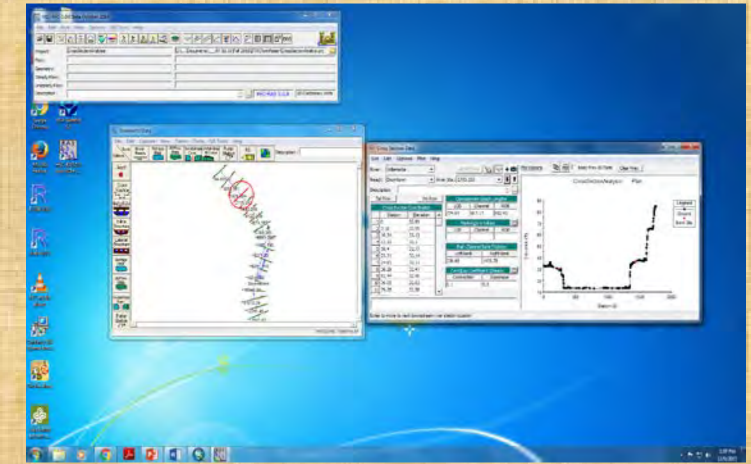
- ❑ When increasing spatial resolution of input DEM from 10m to 1m:
  - Highest flood depth increases **6.5 inches**.
  - The flooded areas are broaden in **northwest** of the river segment.
- ❑ The simulated flooded extent does not cover the FEMA flood area in the **middle east** of river segment.

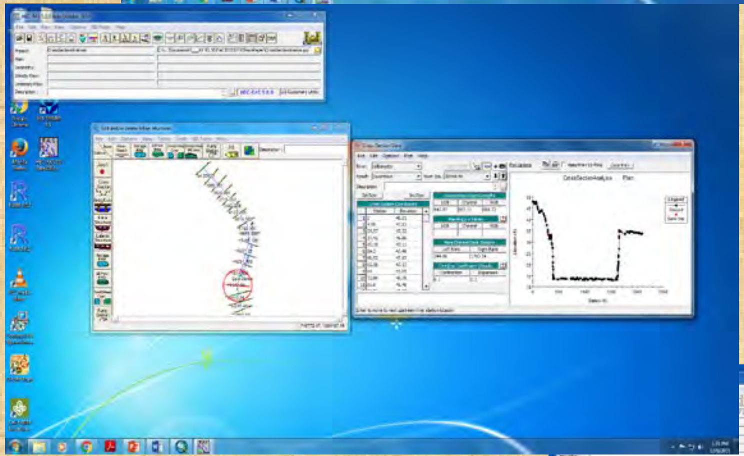




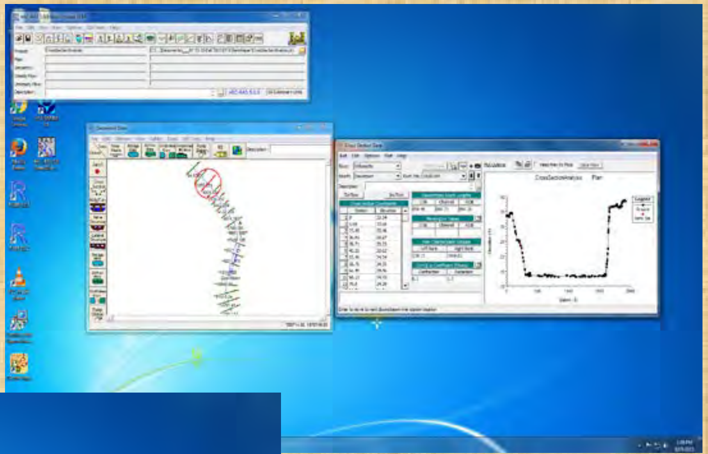








Other Findings



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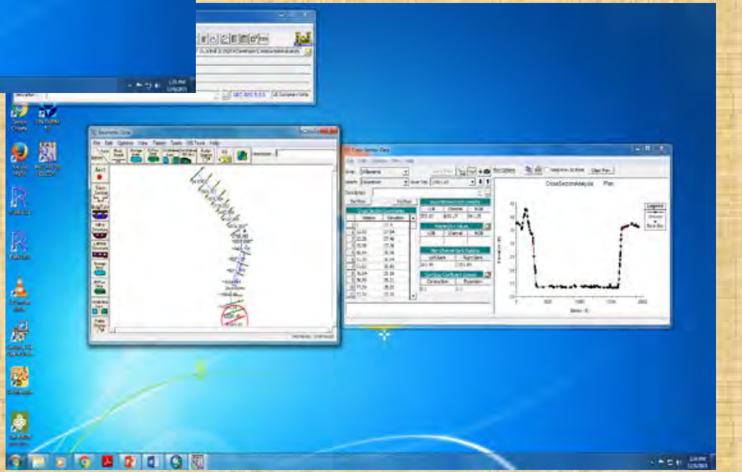

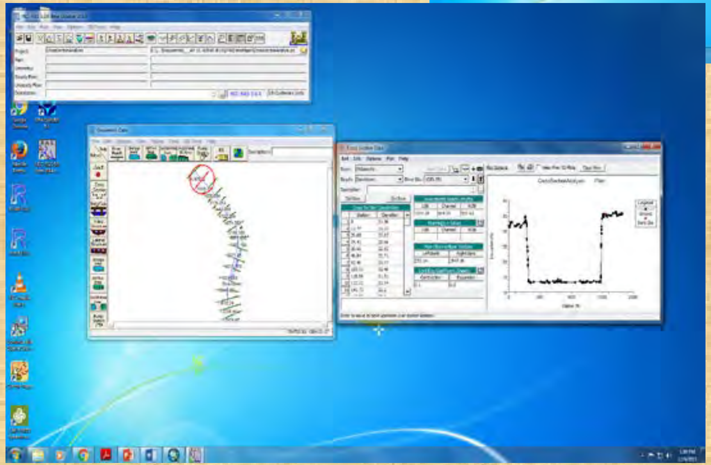

Conclusions:

- ❑When increasing spatial resolution of input DEM:
- Simulated upstream flood:
  - Highest flood depth increases.
  - The flooded areas are broaden.
- ❑The simulated flooded extent does not cover the FEMA flood area in the **middle east** of river segment.
- ❑Upstream flood likely happens in southeast and northwest than other sides of the river segment, due to the low elevation.

References

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