Mapping and Predicting Flood Inundation in TN

Geohazards Impacting Transportation in the Appalachian Region – 11th Annual Technical Forum

Chattanooga, TN – August 3, 2011

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Problem

- Two major flood events in Tennessee since May 2010
- Emergency responders and the general public need accurate information quickly

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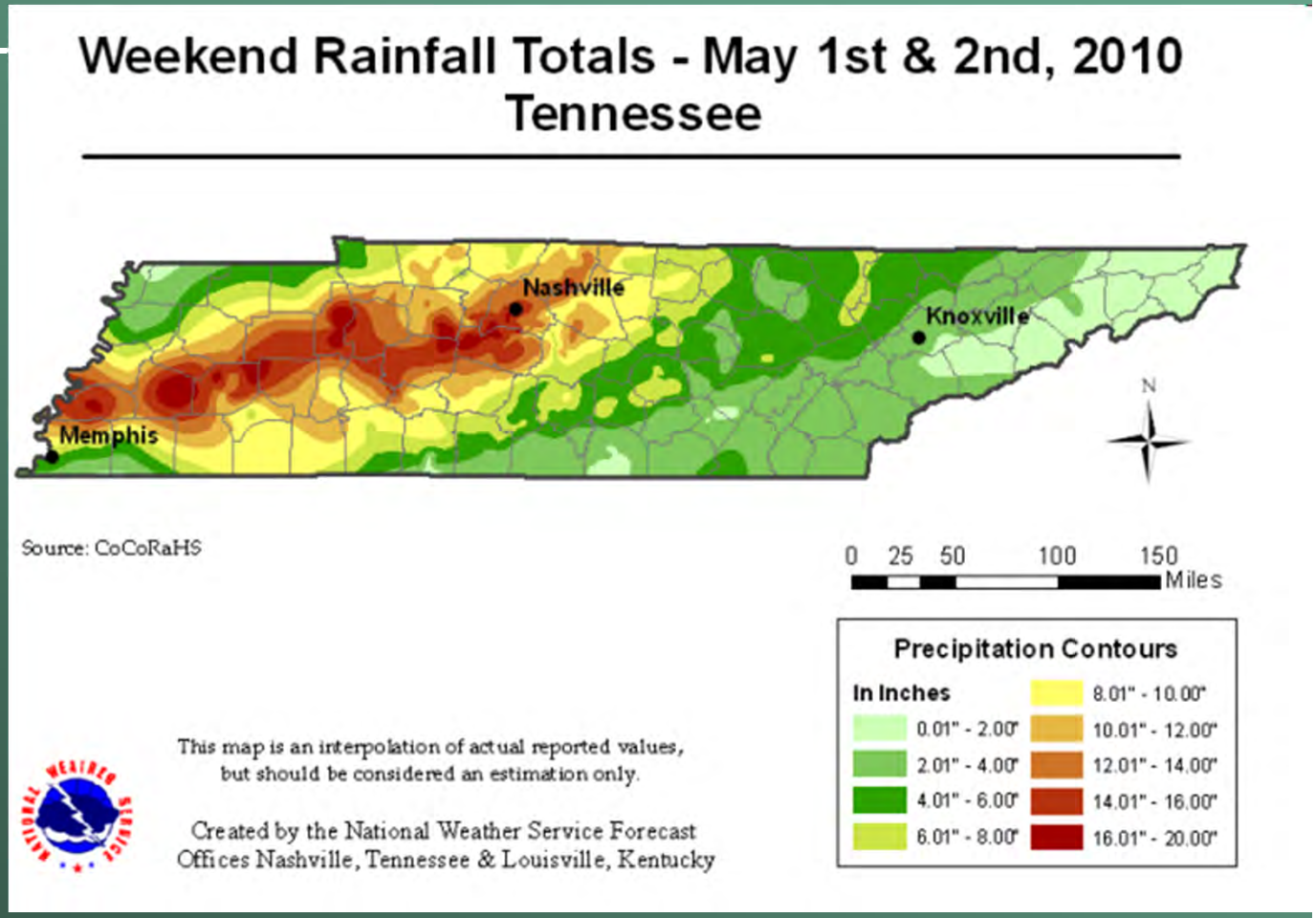
Background

May 2010

- Lower Cumberland
  - 15 to 20 inches
  - Limited flood storage
  - Historic flows at most tribs.



USGS

Background

Nashville

- Cumberland River
  - Old Hickory Dam (mile 215)
  - Downtown Nash. (mile 190)
  - Cheatham Dam (mile 151)

- Tribs.
  - 6 small urban tribs
    - Mansker Creek
    - Dry Creek
    - Mill Creek
    - Browns Creek
    - Richland Creek
    - Whites Creek
  - Stones R. (Regulated)
  - Harpeth River (870 sq mi.)

USGS


NASHVILLE SCENE
THE FLOOD


Old Harding Pk.


SAUNDERSVILLE RD
STOP


WZTV
Saturday
NASHVILLE
CNN

USGS


$#!**@&^!!!!!!!!!!!!!!
MY HOUSE!!!

New Collaborative Effort

Multiple Agencies

- Modeling, HWMs, Flood Report
- Forecasting
- GIS & Mapping
- Real-time data
- Others

USGS/USACE/NWS/Metro Nashville

- USGS Install new gages along the Cumberland River
- USACE model hydraulics of main stem and tributaries
- NWS improve prediction models and communications
- USGS deliver real-time inundation maps
- Metro Nashville, OEM develop applications

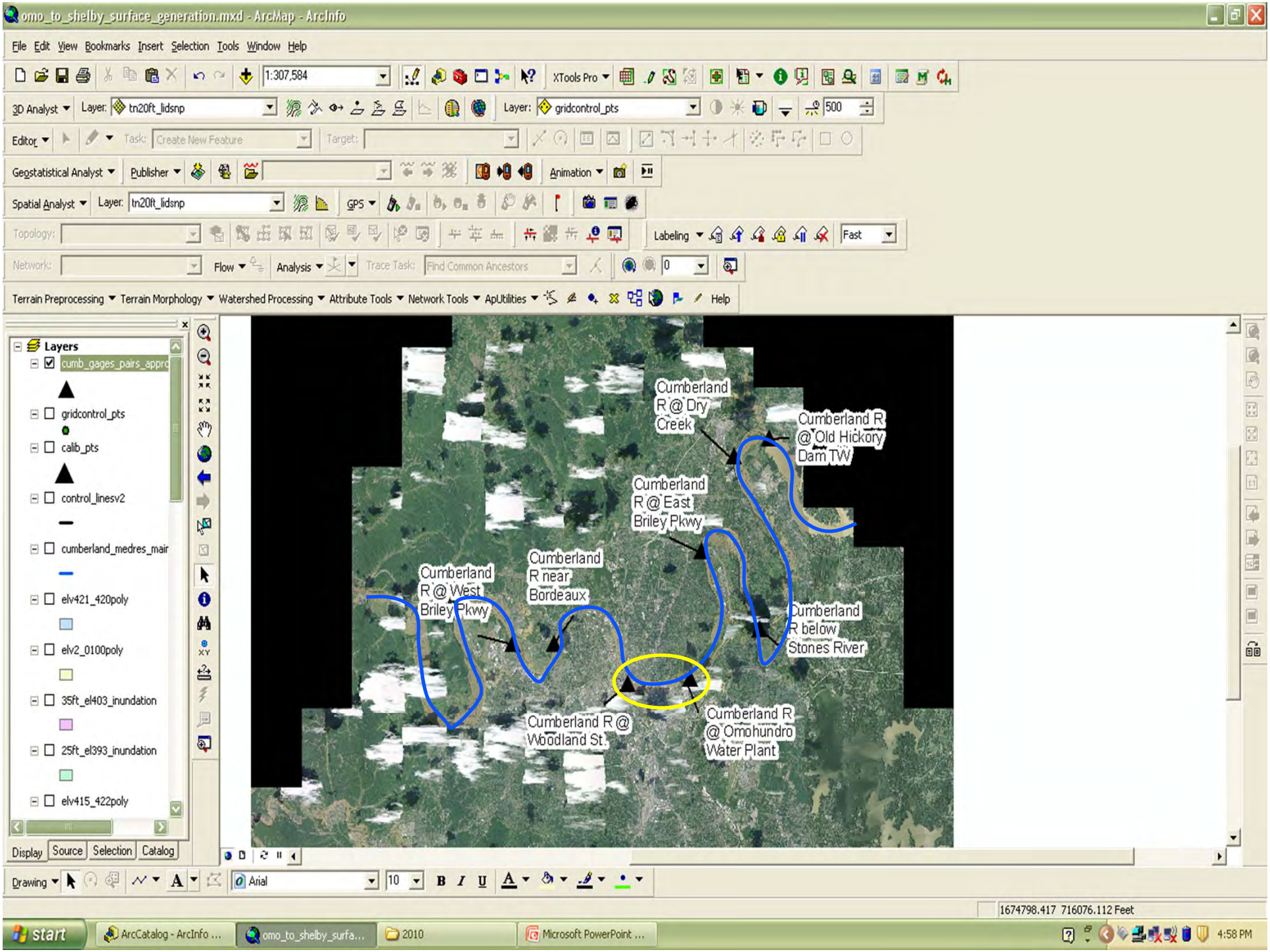
USGS

Gaging on the Cumberland River
(Nashville)

1. Old Hickory TW (mile 215) USACE*
2. At Dry Creek (mile 213)
3. At Stones River (mile 205)
4. At Old Lock #2 (mile 200)
5. US of Downtown Nash. (mile 193)
6. Downtown (mile 190) USACE/USGS*
7. DS of Downtown Nash. (mile 184)
8. At Whites Creek (mile 182)

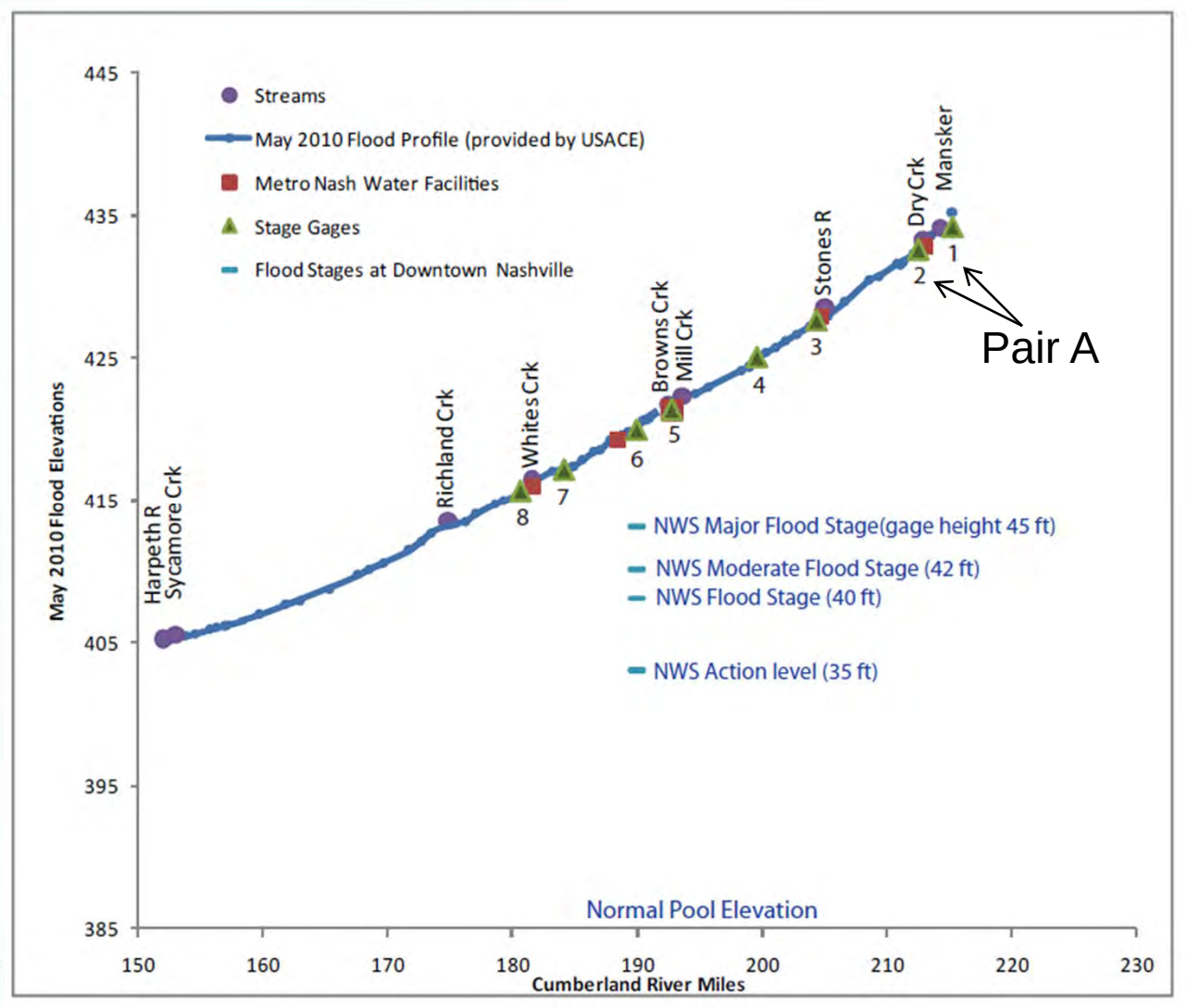
*existing gages

USGS


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
Layers
cumb_gages_pairs_appro
gridcontrol_pts
calib_pts
control_linesv2
cumberland_medres_mair
elv421_420poly
elv2_0100poly
35ft_el403_inundation
25ft_el393_inundation
elv415_422poly
Cumberland R @ Dry Creek
Cumberland R @ Old Hickory Dam TW
Cumberland R @ East Briley Pkwy
Cumberland R near Bordeaux
Cumberland R @ West Briley Pkwy
Cumberland R below Stones River
Cumberland R @ Woodland St.
Cumberland R @ Omohundro Water Plant
1674798.417 716076.112 Feet

Inundation Between Paired Gages

- Linear slope sections
- Evenly spaced stage gages
- Cascading gage pairs



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Building Map Libraries

- **Create inundation maps between gage pairs at 1-foot intervals**

Upstream stage

Downstream stage

Pair X-X	33	34	35	36	37
30	33-30	34-30	35-30	NA	NA
31	33-31	34-31	35-31	36-31	NA
32	33-32	34-32	35-32	36-32	37-32
33	33-33	34-33	35-33	36-33	37-33
34	NA	34-34	35-34	36-34	37-34
35	NA	NA	35-35	36-35	37-35

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Creating Inundation Maps

- Linear profiles in sections along center line
- Cross-sectional controls
- Surface interpolation with boundaries
- Intersection with LiDAR (or best elevation data)
- Validation against modeled surfaces

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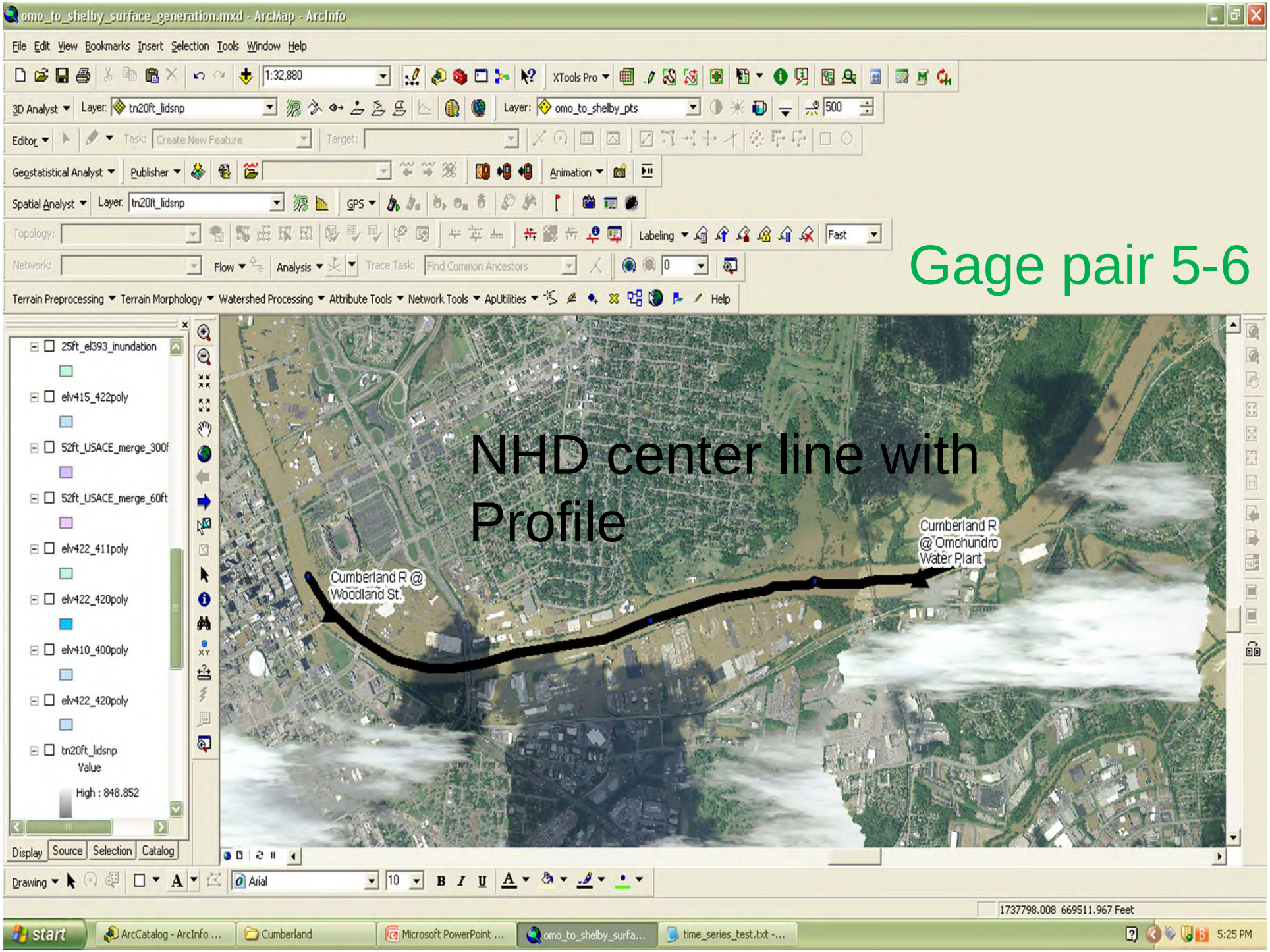
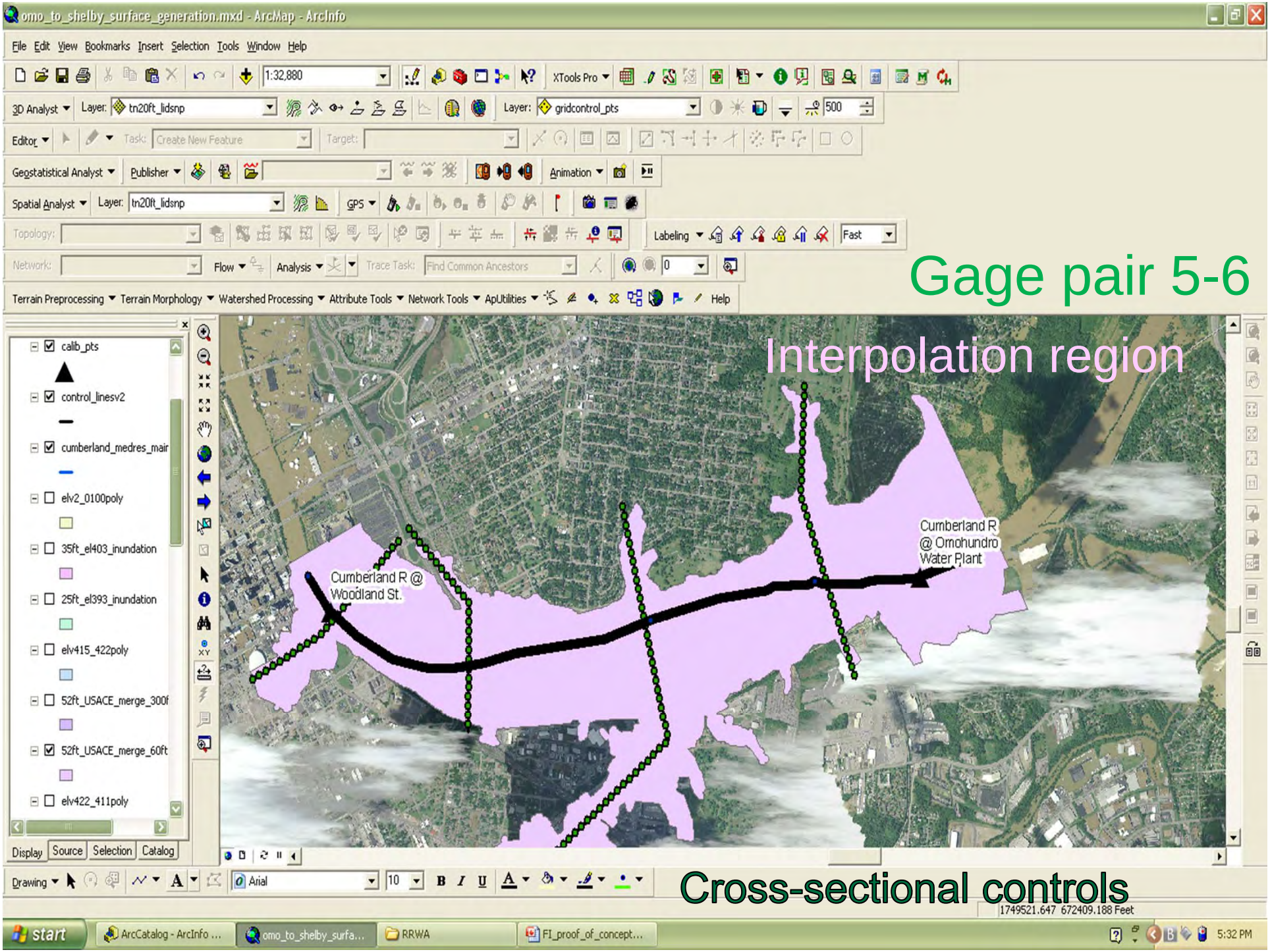
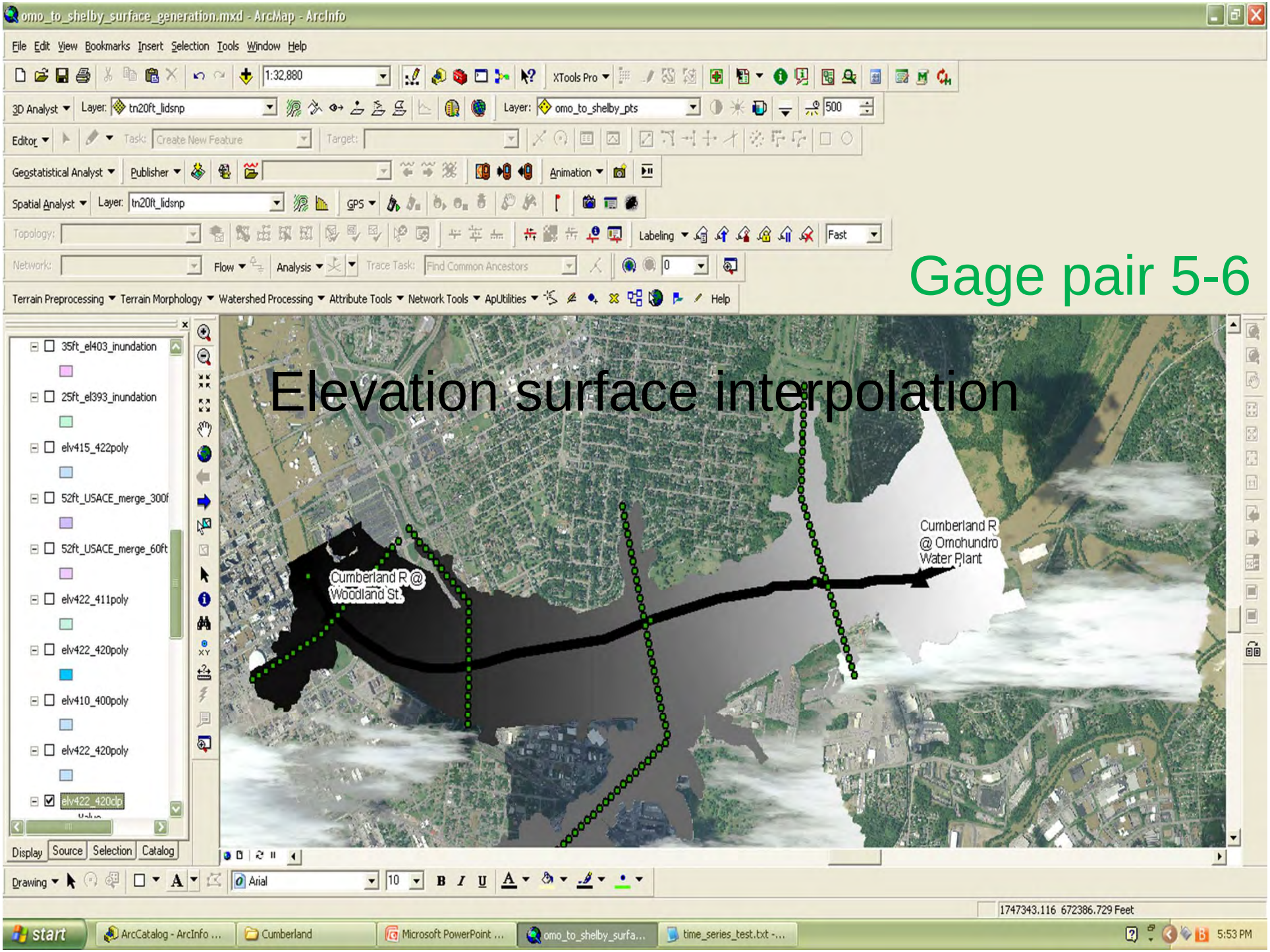
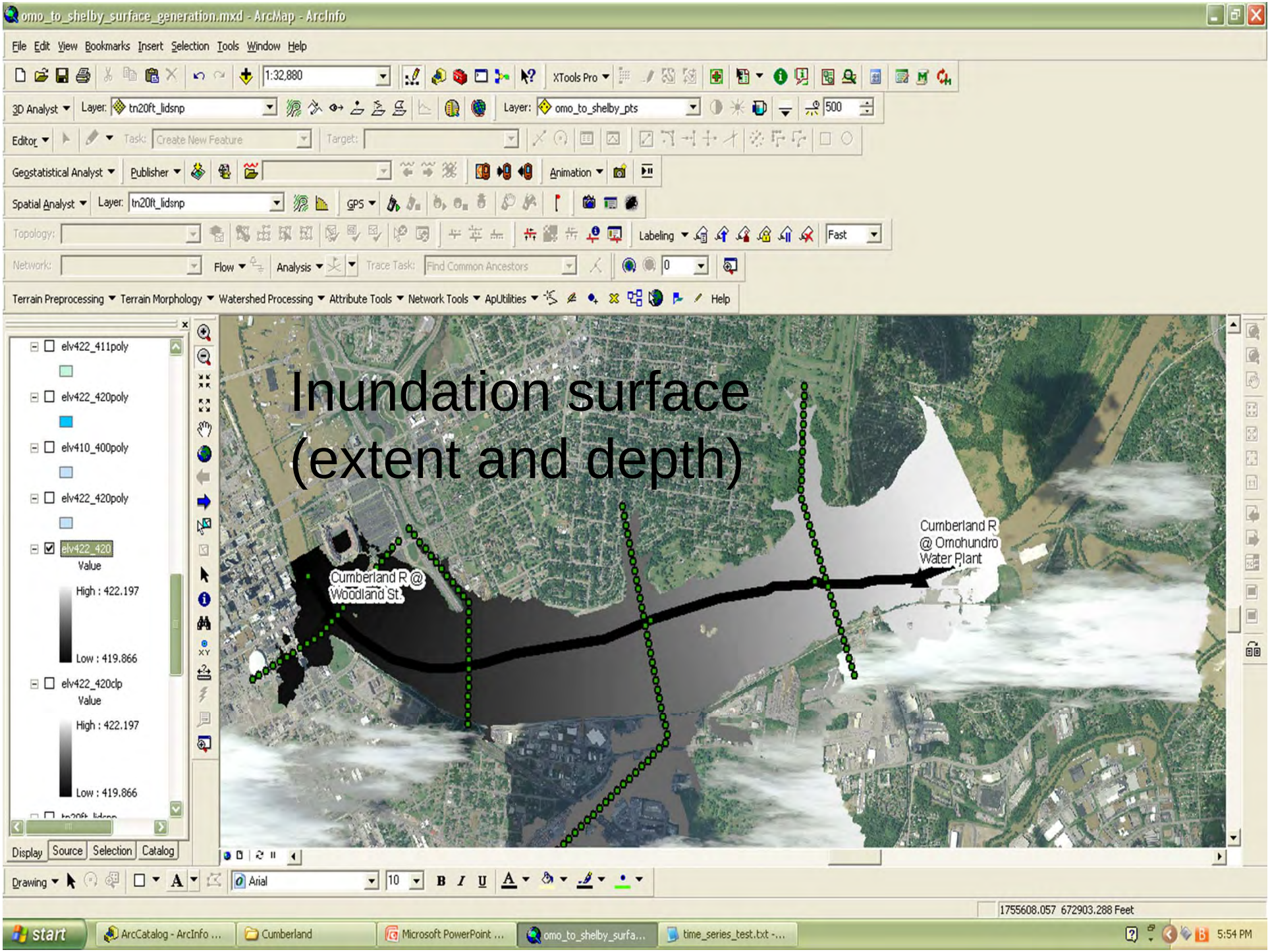
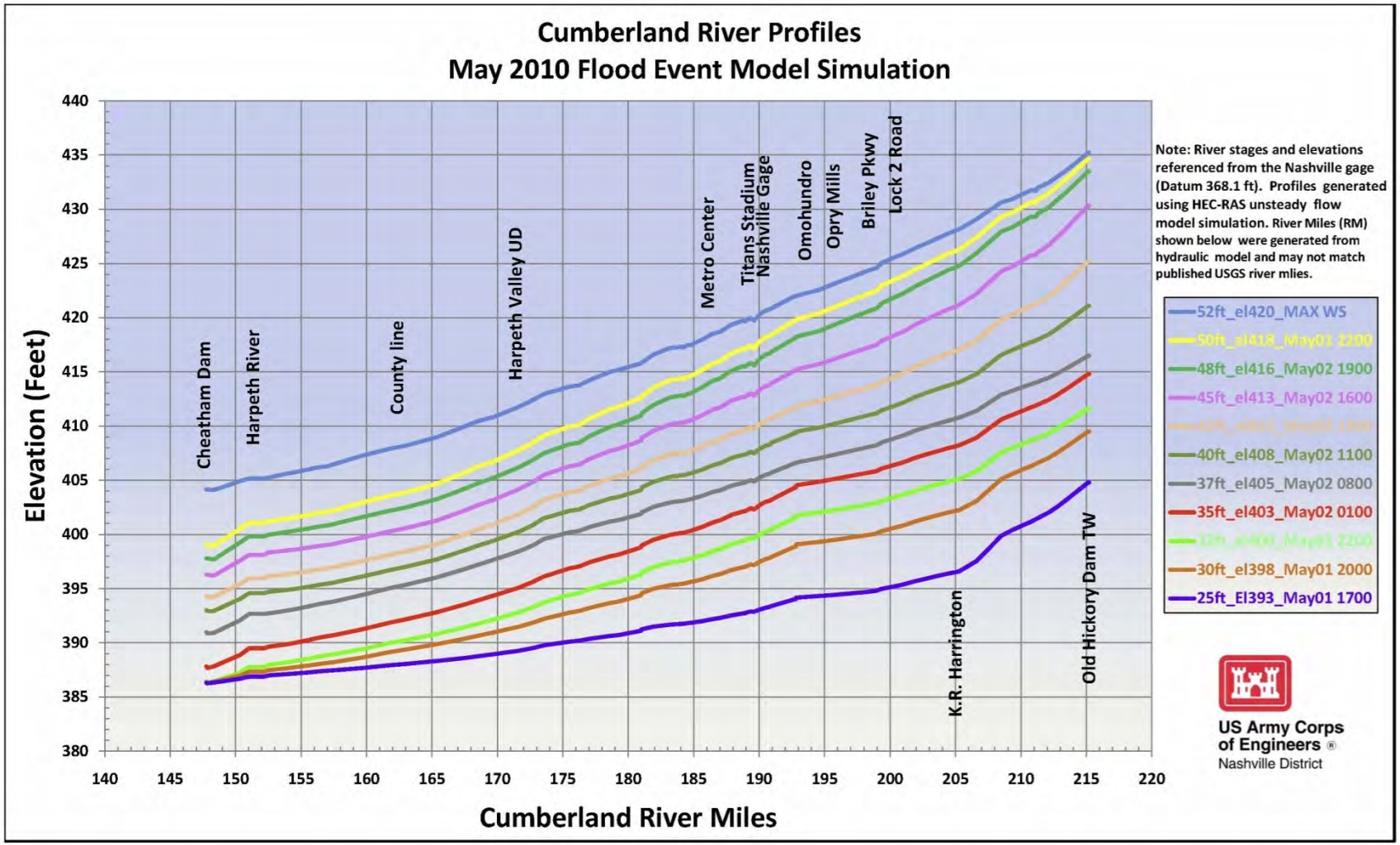

omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
Gage pair 5-6
NHD center line with Profile
Cumberland R @ Woodland St.
Cumberland R @ Omohundro Water Plant
25ft_el393_inundation
elv415_422poly
52ft_USACE_merge_300f
52ft_USACE_merge_60ft
elv422_411poly
elv422_420poly
elv410_400poly
elv422_420poly
tn20ft_lidsnp
Value
High : 848.852
1737798.008 669511.967 Feet


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
Gage pair 5-6
Interpolation region
Cumberland R @ Woodland St.
Cumberland R @ Omohundro Water Plant
Cross-sectional controls
calib_pts
control_linesv2
cumberland_medres_mair
elv2_0100poly
35ft_el403_inundation
25ft_el393_inundation
elv415_422poly
52ft_USACE_merge_300f
52ft_USACE_merge_60ft
elv422_411poly


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
Gage pair 5-6
Elevation surface interpolation
Cumberland R @ Woodland St.
Cumberland R @ Omohundro Water Plant
35ft_el403_inundation
25ft_el393_inundation
elv415_422poly
52ft_USACE_merge_300f
52ft_USACE_merge_60ft
elv422_411poly
elv422_420poly
elv410_400poly
elv422_420poly
elv422_420clp
1747343.116 672386.729 Feet


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
Inundation surface
(extent and depth)
Cumberland R @
Woodland St.
Cumberland R
@ Omohundro
Water Plant
elv422_411poly
elv422_420poly
elv410_400poly
elv422_420poly
elv422_420
Value
High : 422.197
Low : 419.866
elv422_420clp
Value
High : 422.197
Low : 419.866
Display
Source
Selection
Catalog
1755608.057 672903.288 Feet



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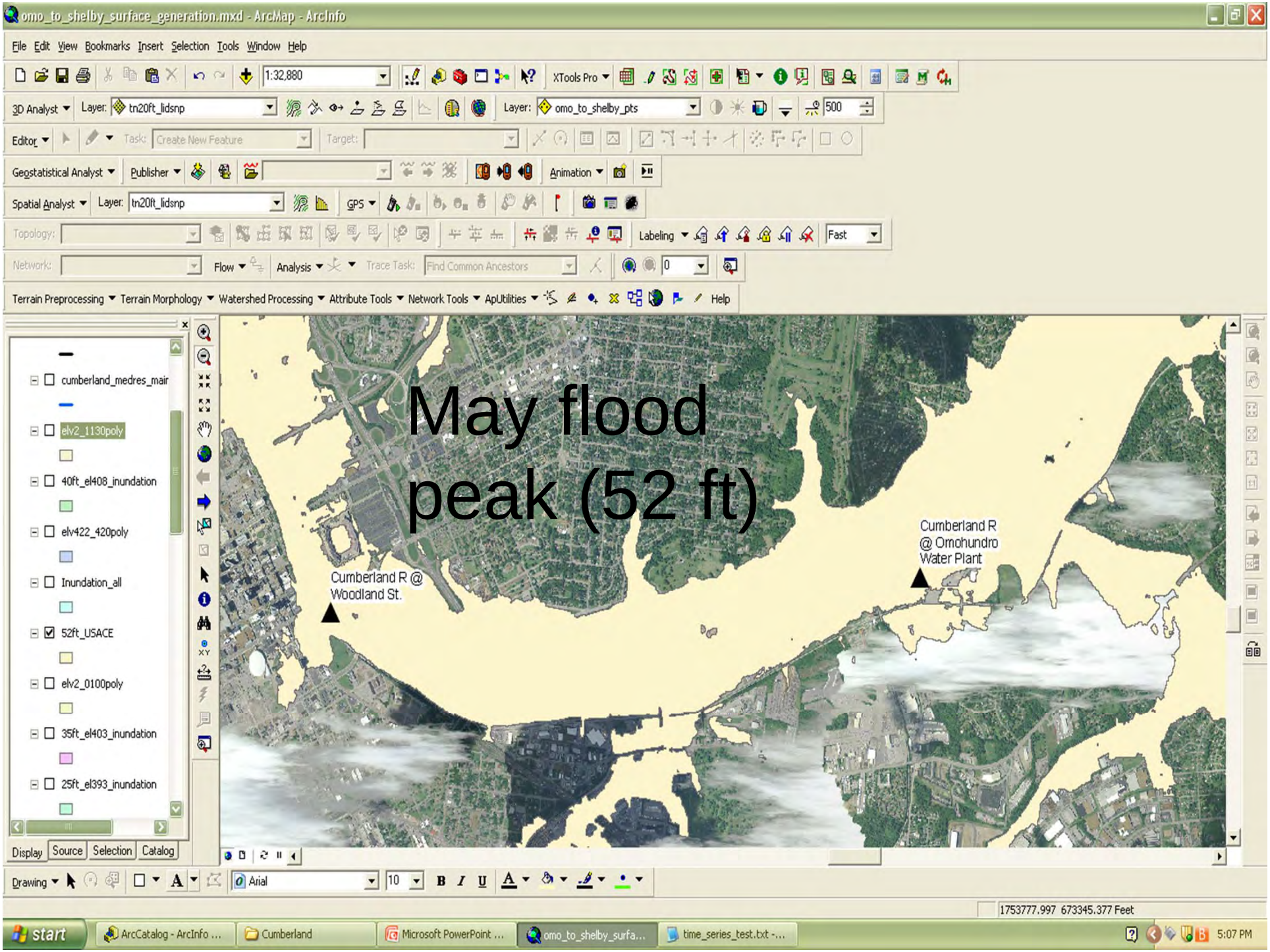
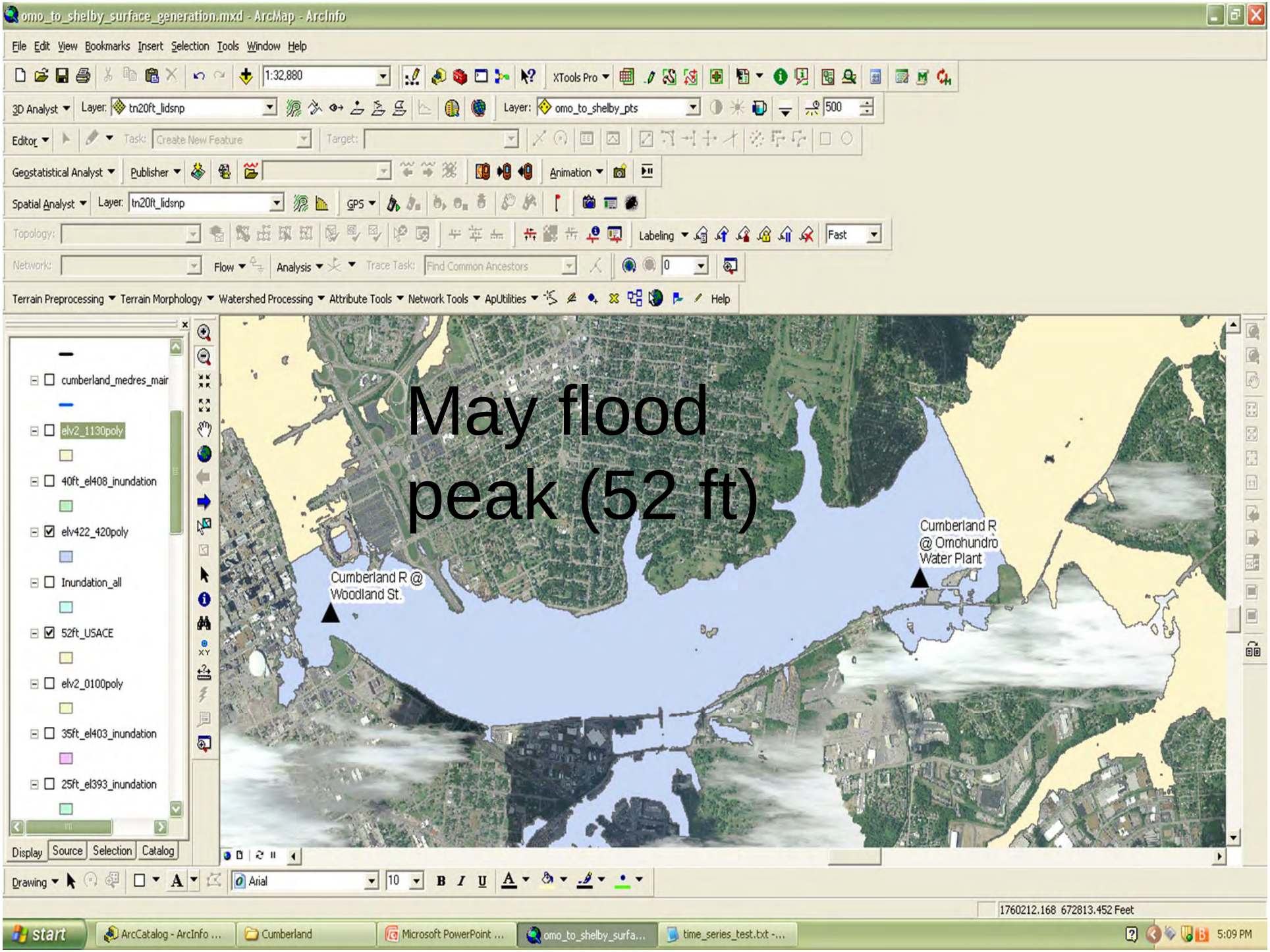
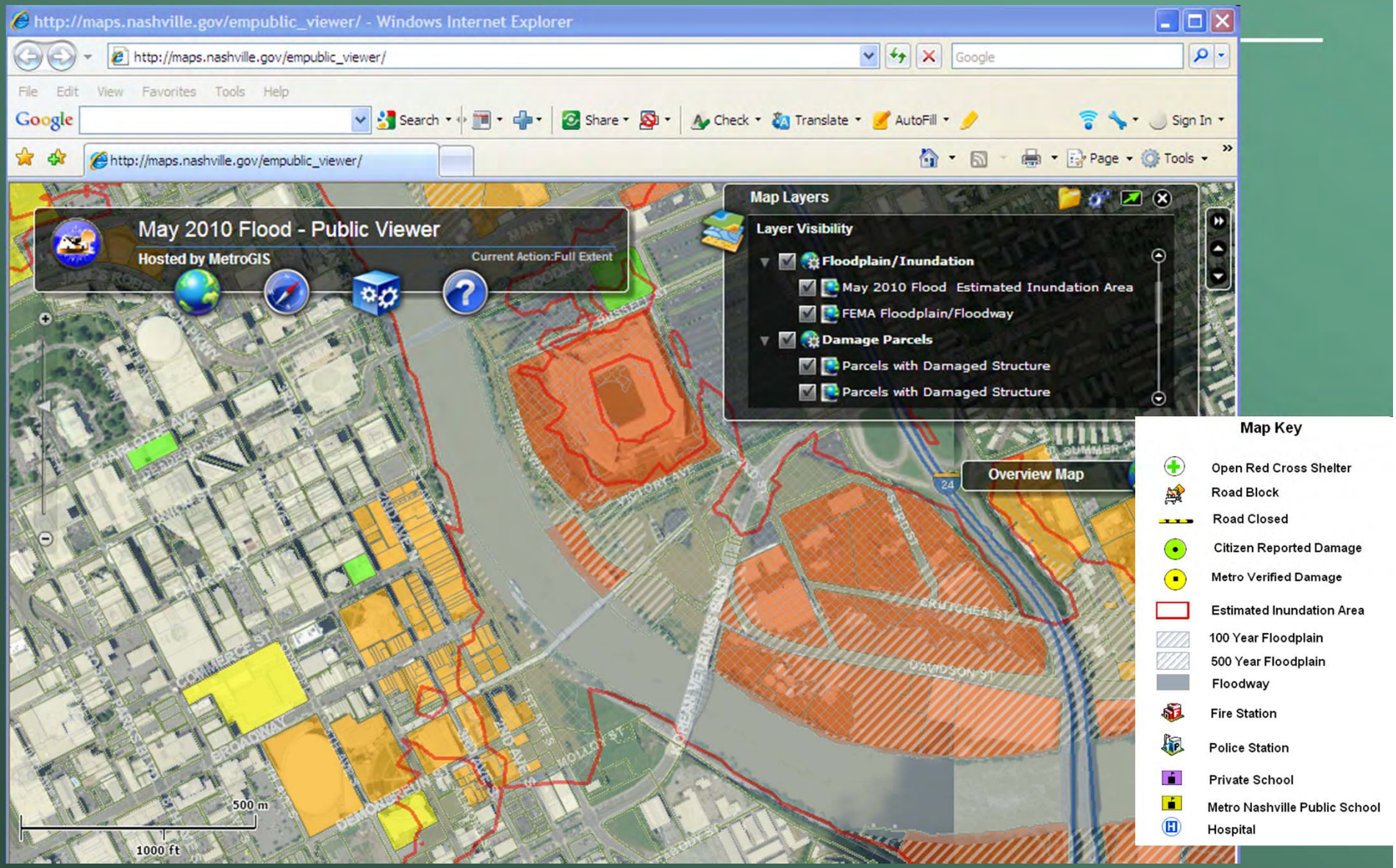
Validation against modeled surfaces


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
1:32,880
XTools Pro
3D Analyst
Layer: tn20ft_lidsnp
Layer: omo_to_shelby_pts
500
Editor
Task: Create New Feature
Target:
Geostatistical Analyst
Publisher
Animation
Spatial Analyst
Layer: tn20ft_lidsnp
GPS
Topology:
Labeling
Fast
Network:
Flow
Analysis
Trace Task:
Find Common Ancestors
Terrain Preprocessing
Terrain Morphology
Watershed Processing
Attribute Tools
Network Tools
ApUtilities
Help
cumberland_medres_mair
elv2_1130poly
40ft_el408_inundation
elv422_420poly
Inundation_all
52ft_USACE
elv2_0100poly
35ft_el403_inundation
25ft_el393_inundation
Display
Source
Selection
Catalog
May flood peak (52 ft)
Cumberland R @ Woodland St.
Cumberland R @ Omohundro Water Plant
Drawing
Arial
10
1753777.997 673345.377 Feet
start
ArcCatalog - ArcInfo ...
Cumberland
Microsoft PowerPoint ...
omo_to_shelby_surfa...
time_series_test.txt -...
5:07 PM


omo_to_shelby_surface_generation.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
1:32,880
XTools Pro
3D Analyst
Layer: tn20ft_lidsnp
Layer: omo_to_shelby_pts
500
Editor
Task: Create New Feature
Target:
Geostatistical Analyst
Publisher
Animation
Spatial Analyst
Layer: tn20ft_lidsnp
GPS
Topology:
Labeling
Fast
Network:
Flow
Analysis
Trace Task:
Find Common Ancestors
Terrain Preprocessing
Terrain Morphology
Watershed Processing
Attribute Tools
Network Tools
ApUtilities
Help
cumberland_medres_mair
elv2_1130poly
40ft_el408_inundation
elv422_420poly
Inundation_all
52ft_USACE
elv2_0100poly
35ft_el403_inundation
25ft_el393_inundation
Display
Source
Selection
Catalog
May flood
peak (52 ft)
Cumberland R @
Woodland St.
Cumberland R
@ Omohundro
Water Plant
Drawing
Arial
10
1760212.168 672813.452 Feet
start
ArcCatalog - ArcInfo ...
Cumberland
Microsoft PowerPoint ...
omo_to_shelby_surfa...
time_series_test.txt -...
5:09 PM

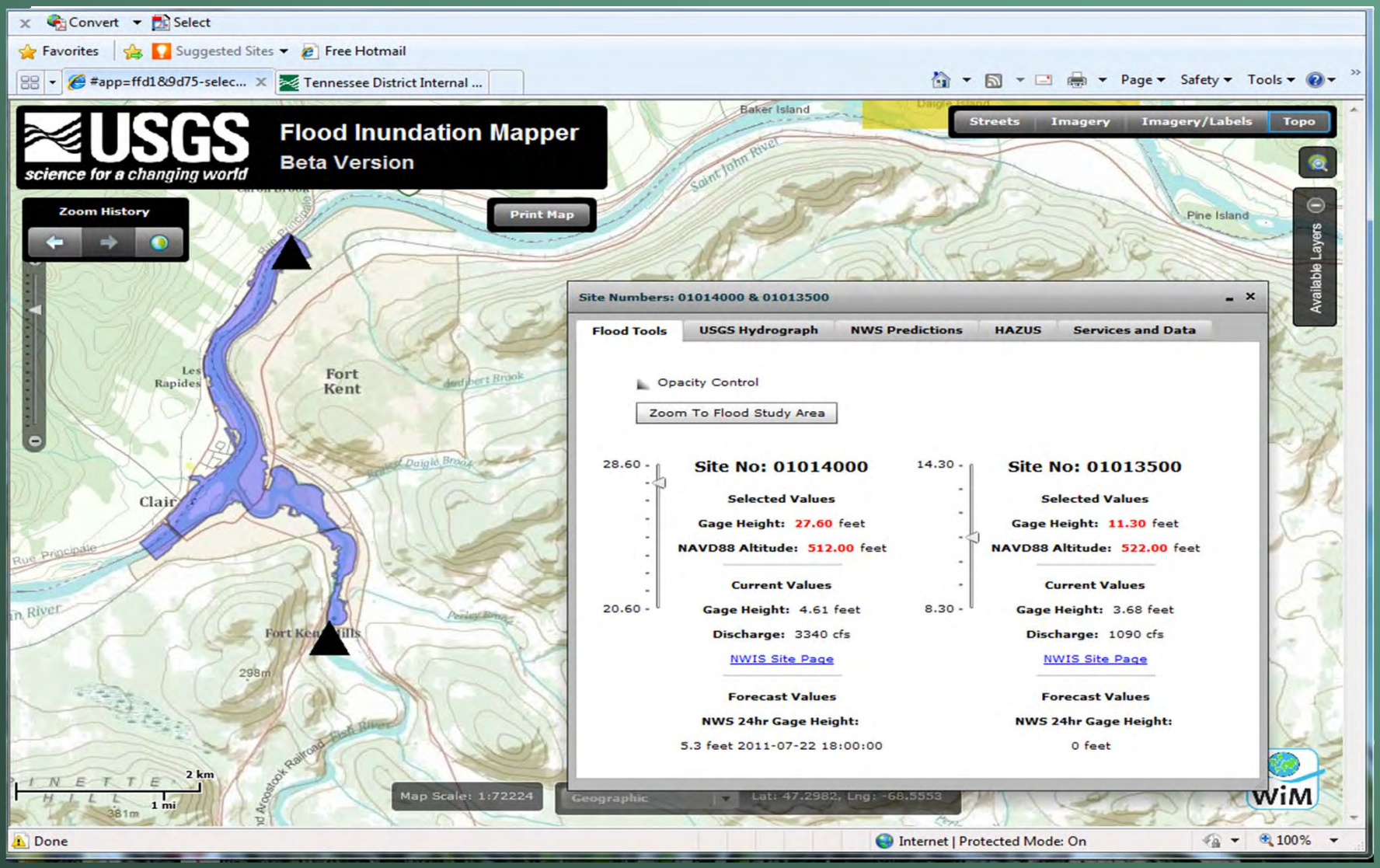
Tools

Metro Nashville Flood Mapping Tool

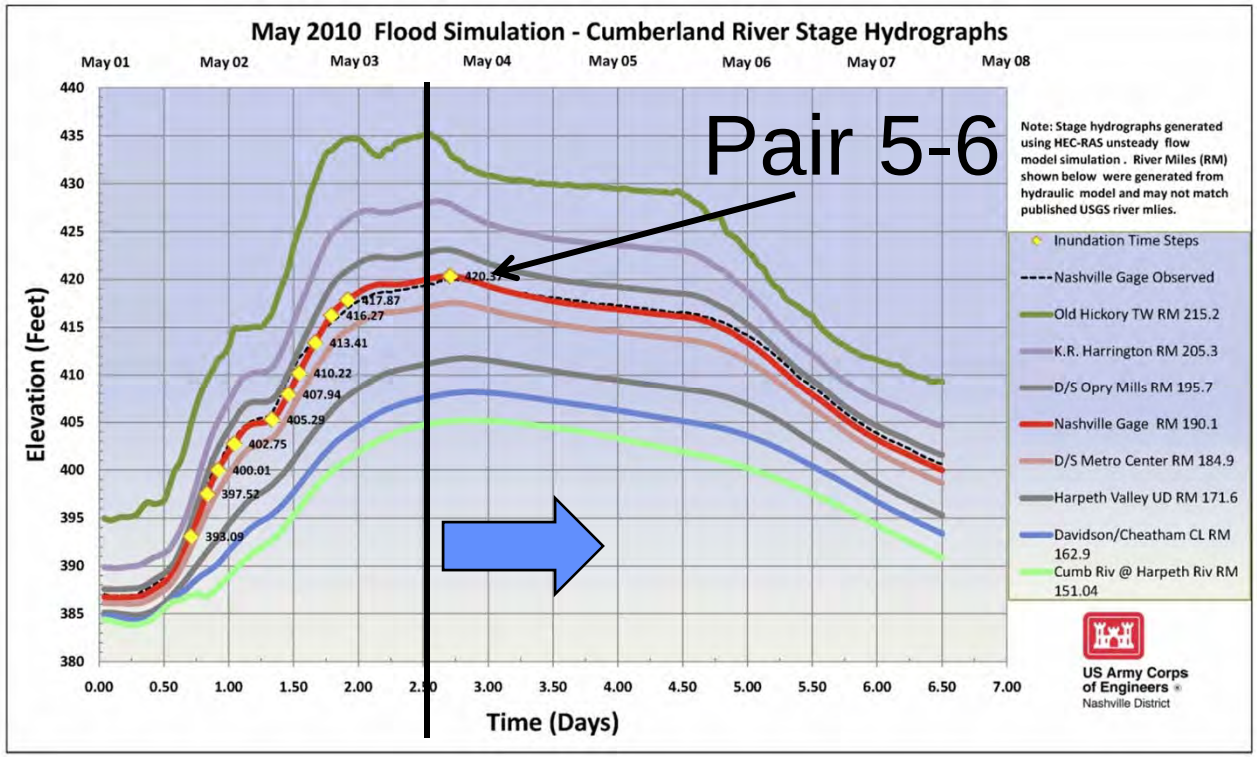


Tools

USGS Flood Mapping Tool (Beta)



Tracking Hydrographs



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Simulation

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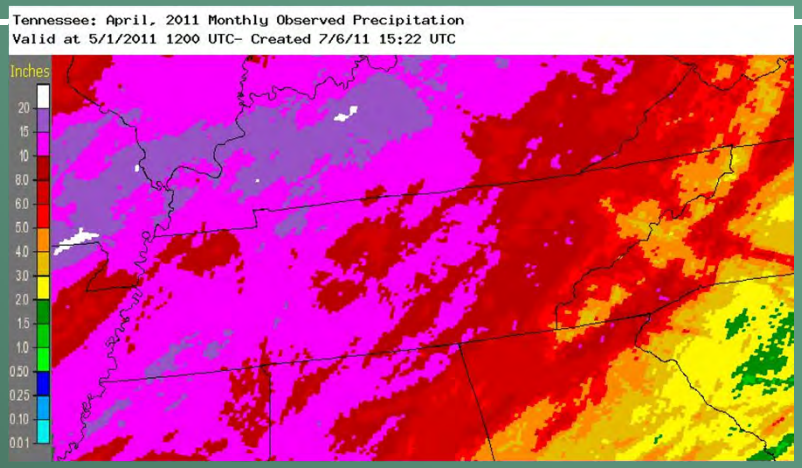
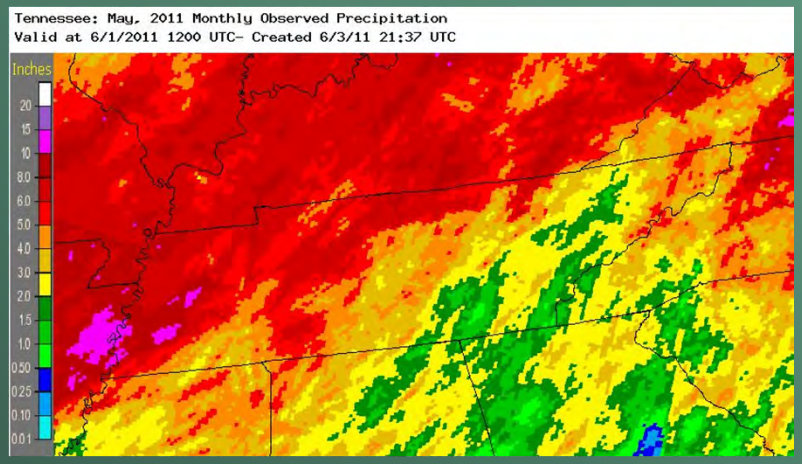
Background

April-May 2011

- **Mississippi River**
  - **Extensive rains in April flooded W TN tribs**
  - **Additional rain in early May and upstream snowmelt flooded the Mississippi River in TN**





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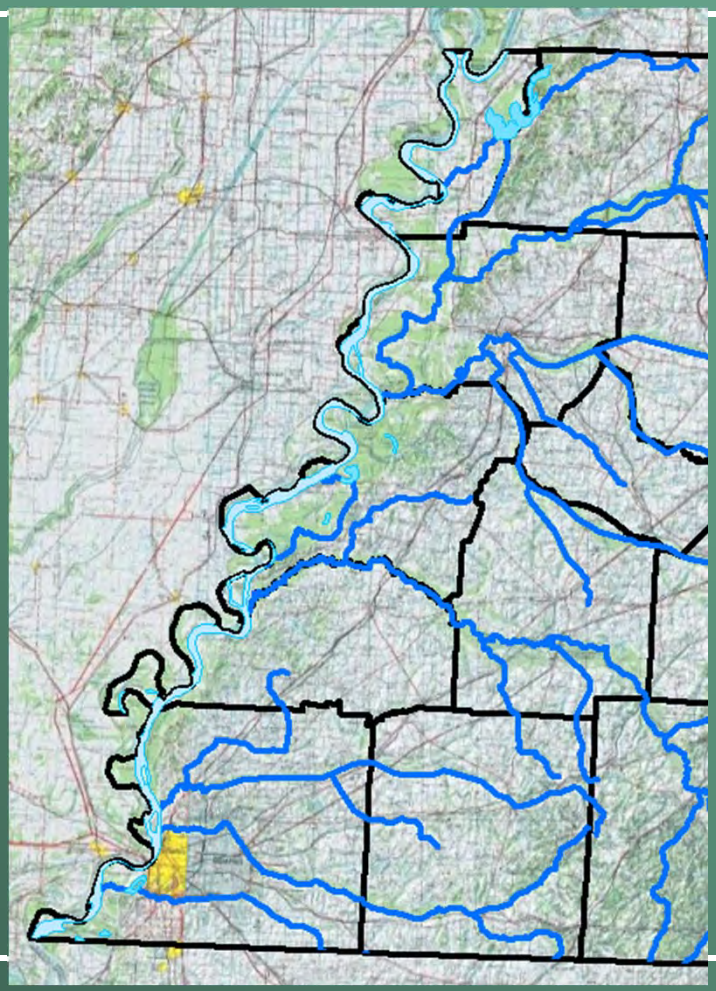
Background

West Tennessee

- Mississippi River
  - Levees protect much of the adjacent land
- Tribs.
  - Obion River
  - Forked Deer – North, Middle, and South Forks
  - Hatchie River
  - Big Creek
  - Loosahatchie River
  - Wolf River
  - Nonconnah Creek



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- The USGS worked with FEMA, USACE, NWS, and local agencies to provide emergency real-time stage data in Shelby County
  - Stage data assisted NWS with forecasts

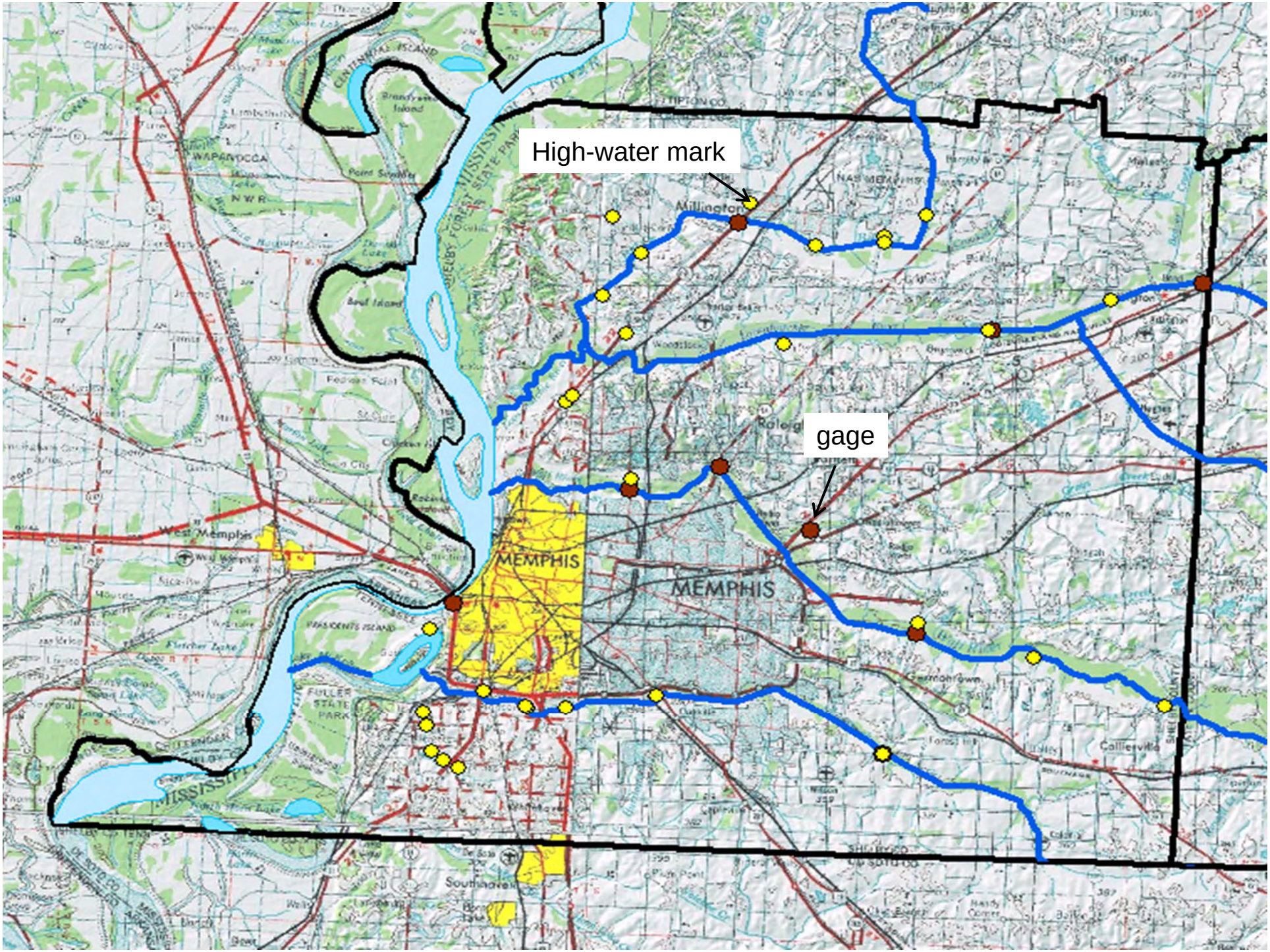
USGS

FEMA / USGS Cooperation

The USGS…

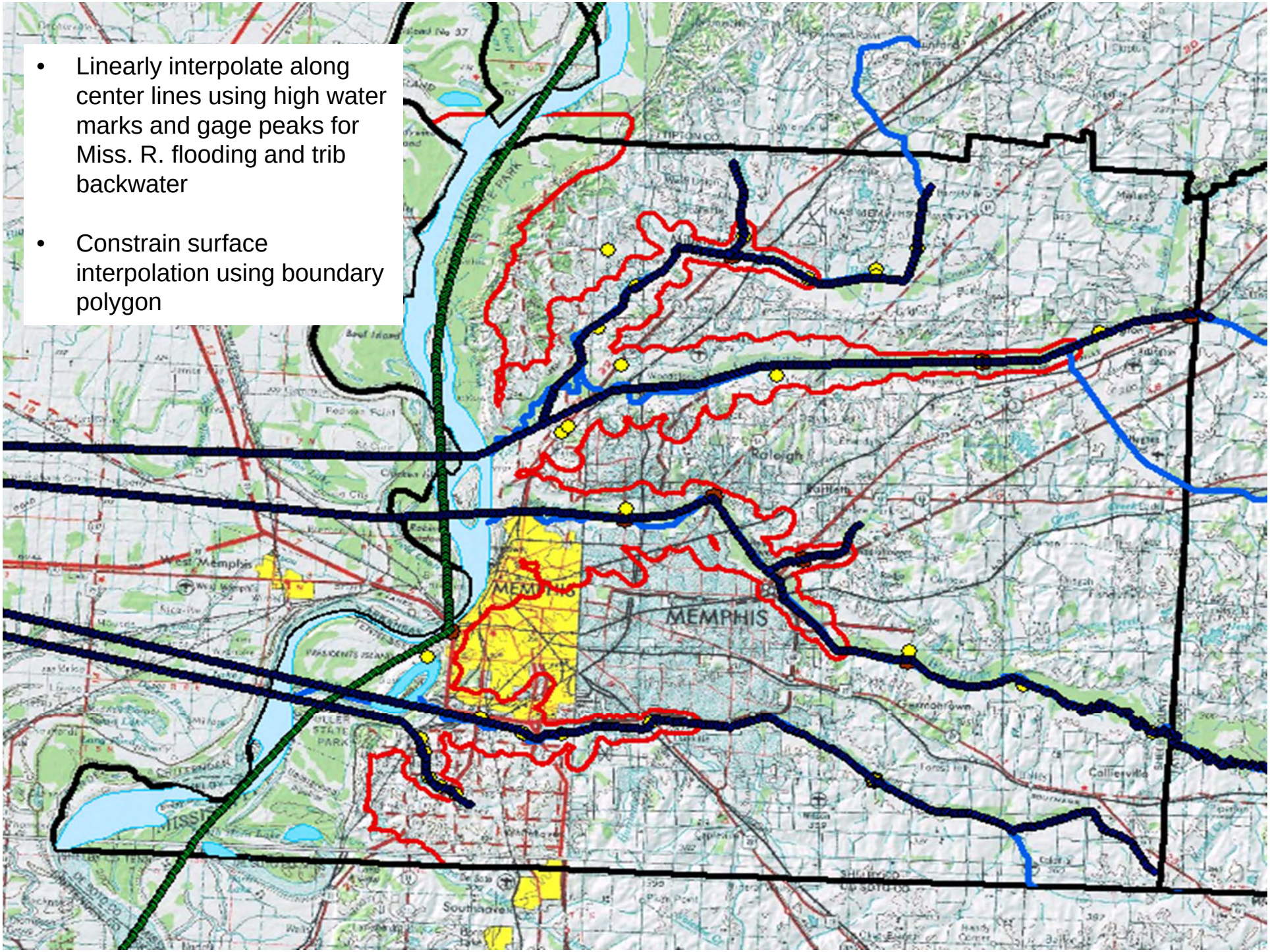
- Collected high-water marks in emergency areas
- Used high-water mark and gage data to map inundation
  - Separate data for the April / May events (where necessary)
  - Process inundation surfaces for both separately
  - Merge the results
- FEMA used data for emergency assistance and to assess damage
  - Timing is important

USGS

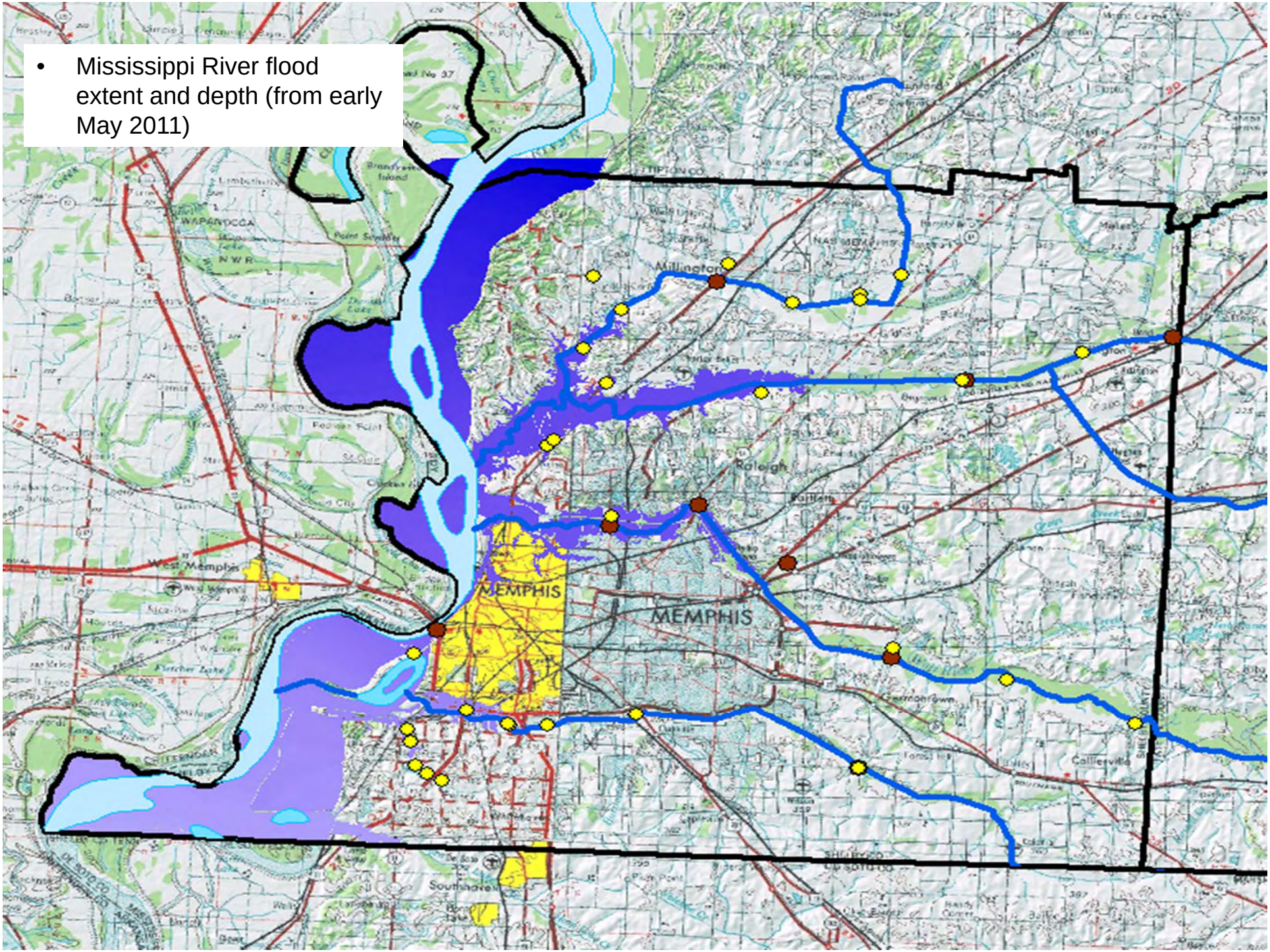

High-water mark
gage
MEMPHIS
MEMPHIS
Millington
West Memphis
Southaven
Collierville
WAPANOCCA
N.W.R.
CENTENNIAL ISLAND
FULLER STATE PARK

- Linearly interpolate along center lines using high water marks and gage peaks for Miss. R. flooding and trib backwater

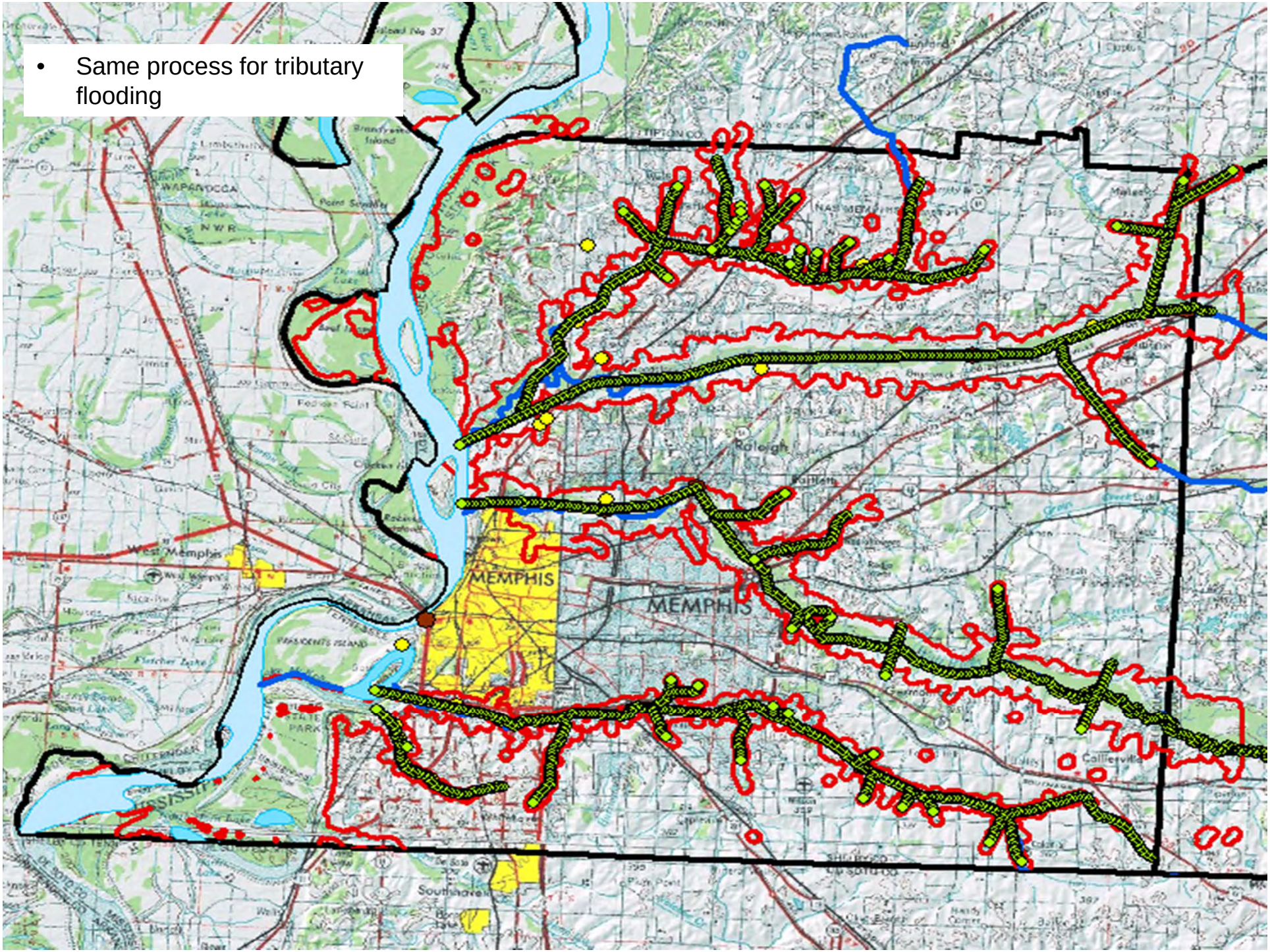
- Constrain surface interpolation using boundary polygon



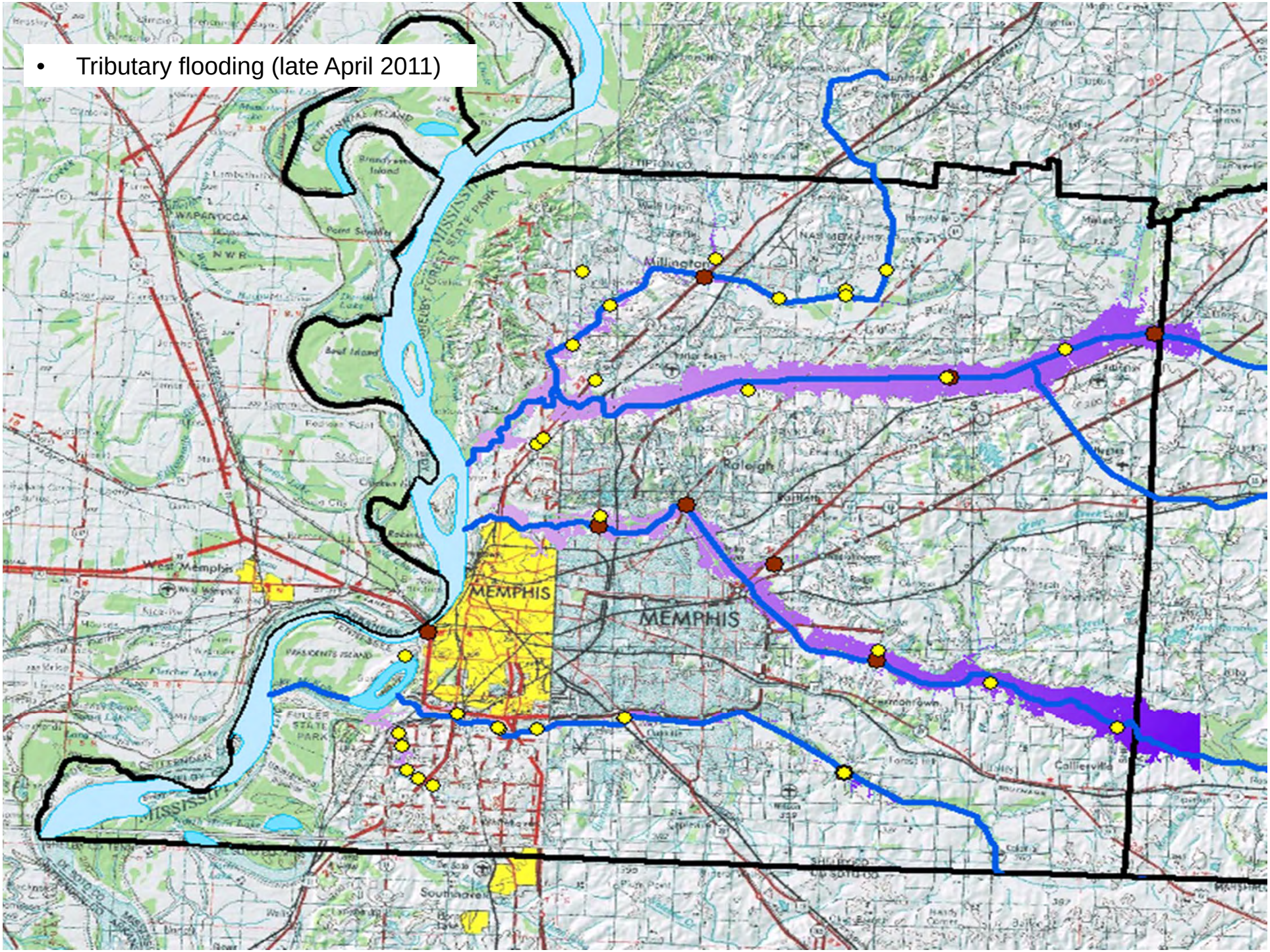
- Mississippi River flood extent and depth (from early May 2011)

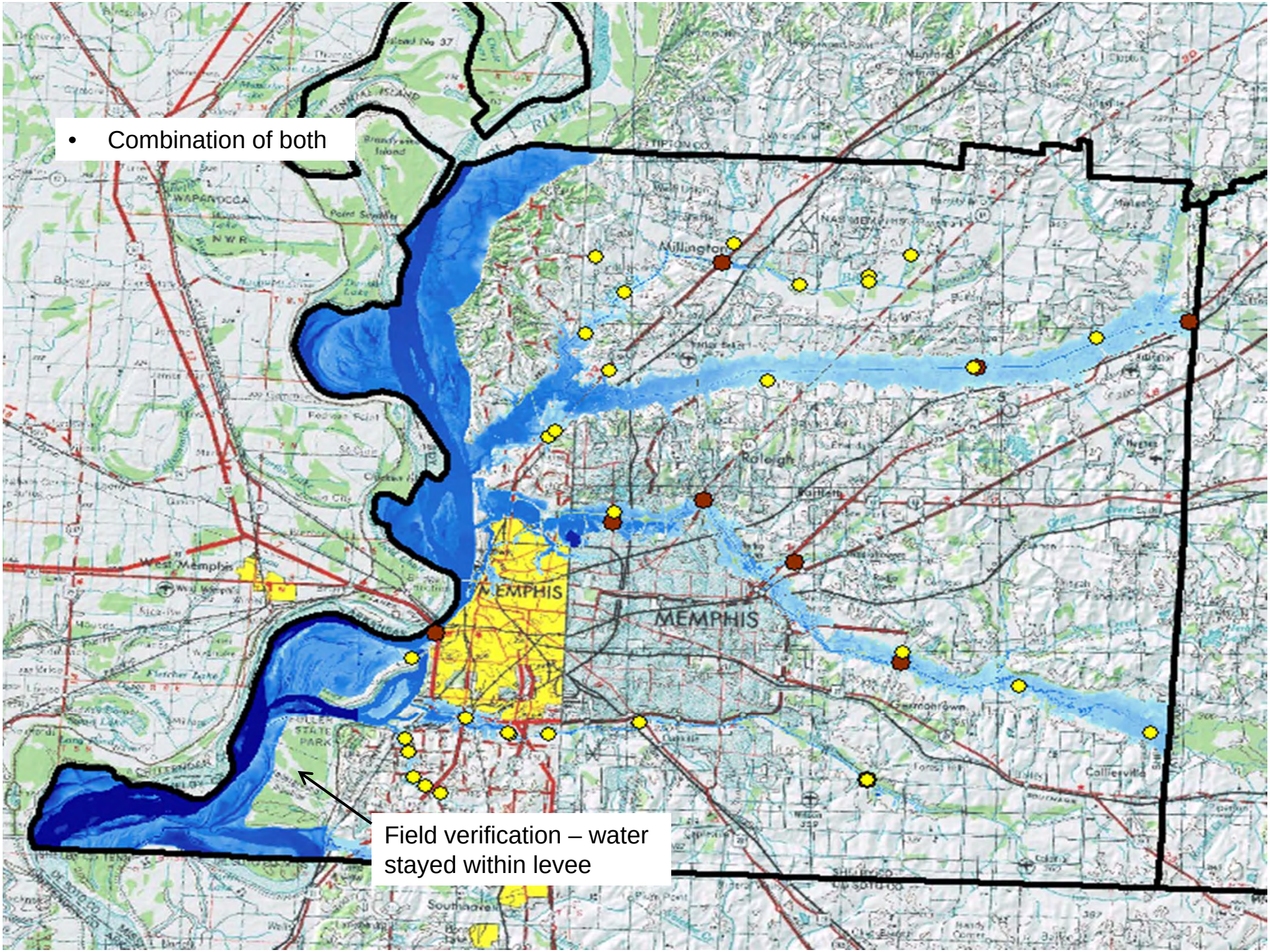


- Same process for tributary flooding



- Tributary flooding (late April 2011)




Combination of both
Field verification – water stayed within levee
MEMPHIS
MEMPHIS
Millington
Raleigh
West Memphis
Germantown
Collierville
Southaven

Conclusions

Using GIS techniques…

- flooding analysis can be conducted in advance to predict inundation under certain stream/river stage conditions
- map libraries can be built and served to depict real-time/predicted inundation
- in combination with sufficient gage/HWM control, inundation extent and depth can be mapped quickly without the use of complex models

USGS

Questions

The Grand Ole Opry House, flooded in 1975: