

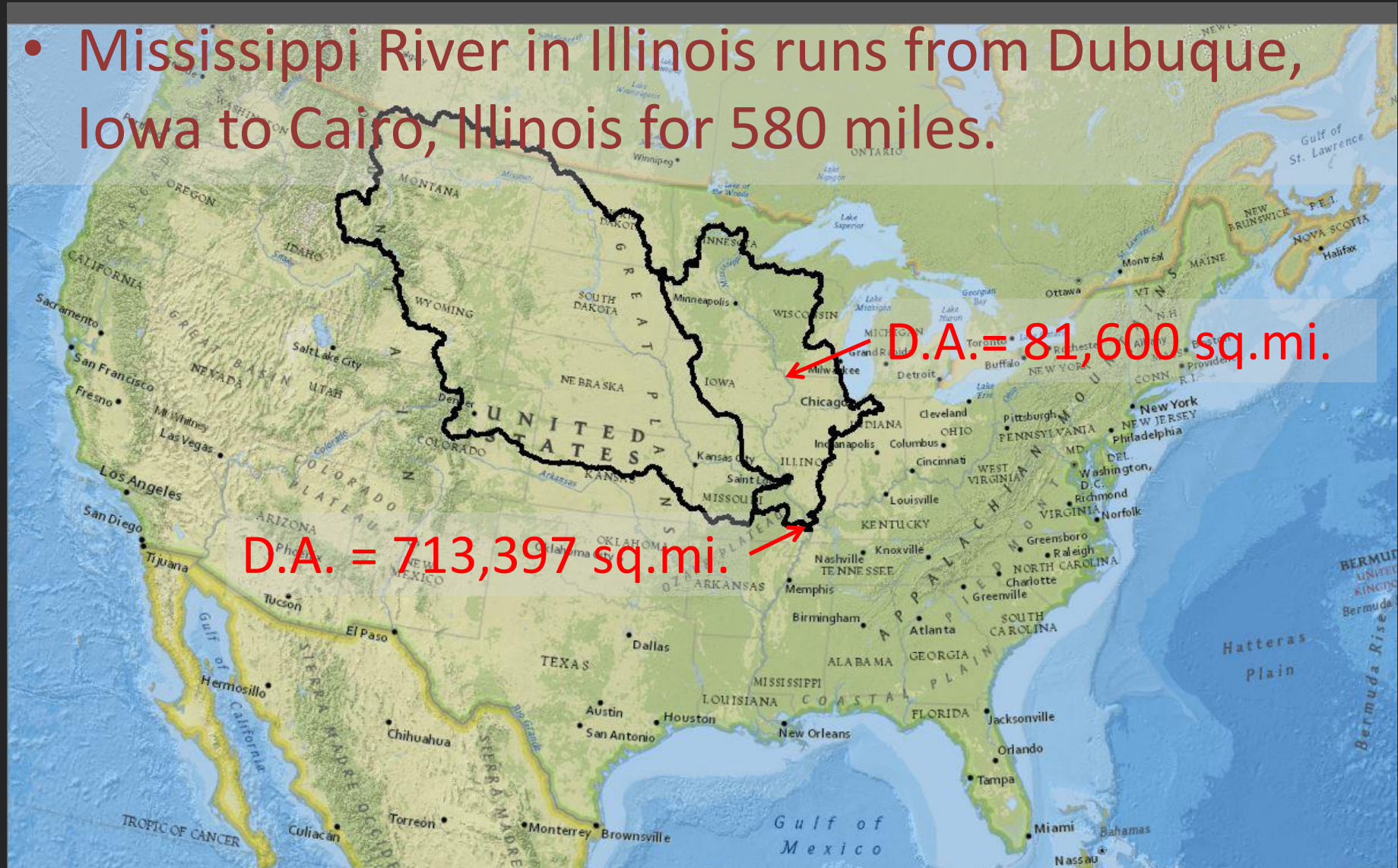
# Inundation Mapping for Unprotected Communities on the Mississippi River





# Mississippi River

- Mississippi River in Illinois runs from Dubuque, Iowa to Cairo, Illinois for 580 miles.



# Mississippi River Flooding



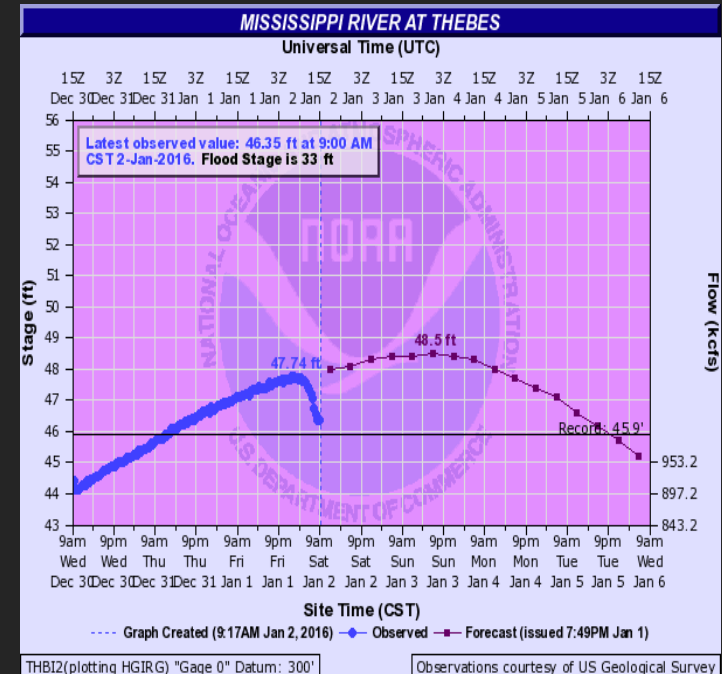
June 2008

April – May 2011





## December 2015 – January 2016





# Emergency Response

- 32 Communities on the Mississippi River are not protected by levees.
- Provide technical guidance to IEMA to assist in their flood fighting operations
  - Report to State Emergency Operations Center
    - Estimate impacts of river forecasts
    - Allocate resources for all impacted areas
    - Assist outside resources (State Incident Management Teams) to understand impacts and provide staging locations.

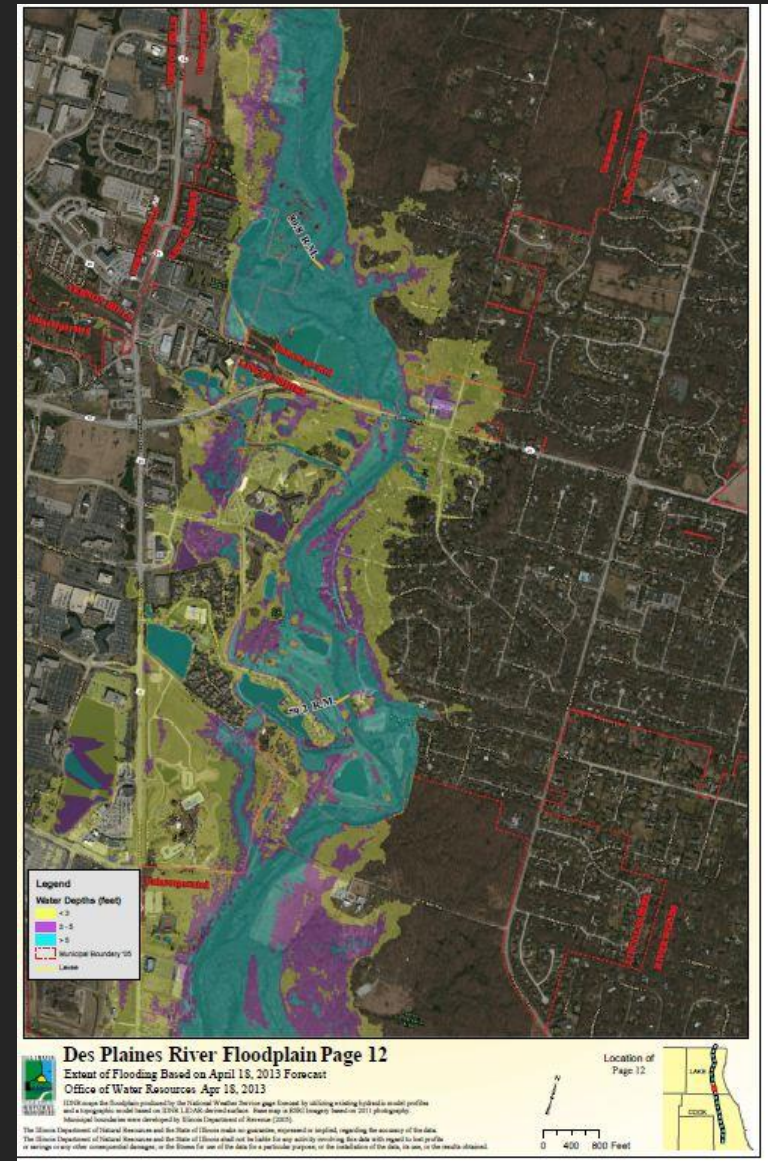
# Flood Inundation Mapping

- What is needed to complete:
  - Hydraulic modeling of the river including several design storm frequencies
    - Upper Mississippi River Flow Frequency Study January 2004
  - High resolution topography data
    - LiDAR Obtained from the U.S. Army Corps of Engineers
  - Stream gage to reference the water surface elevation for both current conditions and forecasted river peak.
    - A network of 28 streamgages along Mississippi River that are NWS forecast points.

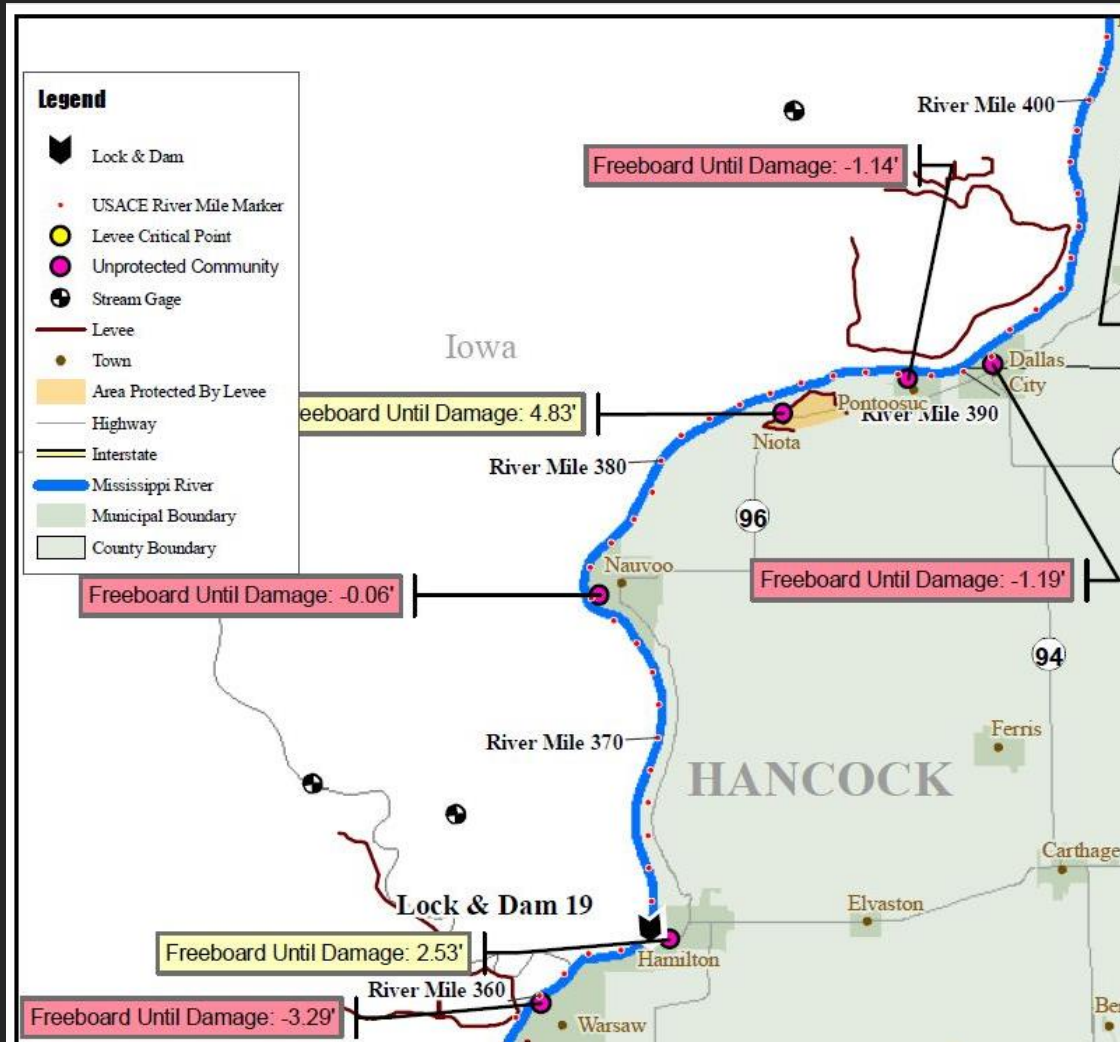


# Dynamic Inundation Mapping

- Based on NWS River Forecasts, hydraulic modeling and high resolution topography
- Includes several stream gages/multiple reaches
- Available for flood response in near-real time



# Unprotected Community Freeboard Analysis

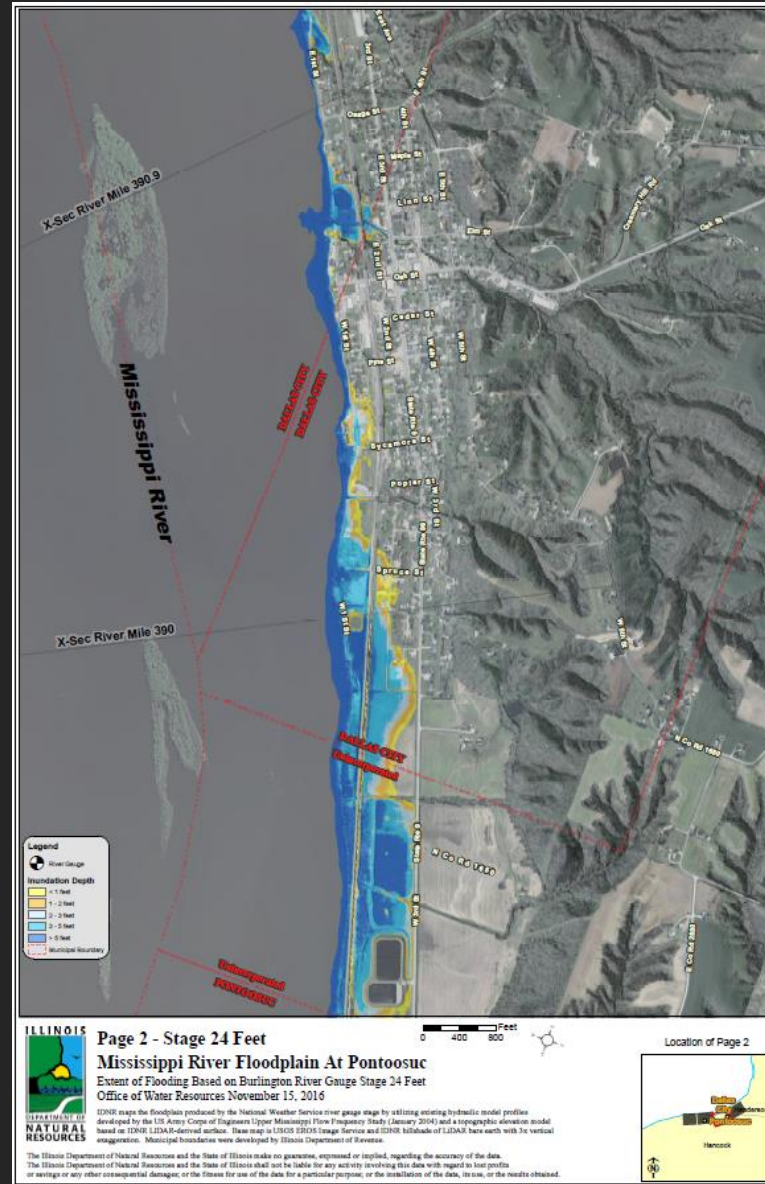


- Developed for the 32 communities along the Mississippi River
- Utilizes the current stage or forecasted crest
- Amount of freeboard and critical elevation determined from field visits during flood events



# Flood Inundation Mapping Methodology

- Map inundation pre-flood
- Uses stage readings at nearby NWS forecast river gauge
- Stage inundation mapped foot by foot using USACE UNET model flood profiles and high resolution topography
- Inundation depth is categorized for emergency response
- Cartographic elements are added and products prepared for distribution



NWS  
river  
forecast  
gauge  
+  
Hydraulic  
model  
+  
LiDAR

# NWS Gauges

<http://water.weather.gov/ahps/>



- NWS gauge elevation used to calculate elevation for each flood stage between 2 year and 500 year frequencies
- NWS used for forecast stage
- Study used 8 gauges along Mississippi near unprotected communities



# UNET Model

- Convert each foot of stage at NWS river gauge to elevation
- Interpolate an event frequency for each elevation between 2 and 500-year event
- Transfer frequency to nearby model cross sections
- Interpolate cross section elevation for each frequency
- Create modeled water surfaces

## Mississippi River Stage Inundation Mapping

Reference River Gauge: Grafton

Community: Grafton, Elsah, Chataqua

Gauge	Reference Elevation (NGVD29)	Flood Stage	Moderate Stage	Major Flood Stage	Historic Crest	Inundation Mapping-vertical adjustment of water surface to datum of LIDAR topo
Grafton	403.79	421.79 (18ft)	427.79 (24ft)	432.79 (29ft)	38.2ft 08/01/1993	-0.19 ft

### At Grafton Gauge (RM 218.02)

Stage Reading/Stage Elevation(NGVD29)/ Corresponding flood frequency based On UNET Model

Stage 19'	Stage 20'	Stage 21'	Stage 22'	Stage 23'	Stage 24'	Stage 25'	Stage 26'	Stage 27'	Stage 28'	Stage 29'	Stage 30'
Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev
422.8'	423.8'	424.8'	425.8'	426.8'	427.8'	428.8'	429.8'	430.8'	431.8'	432.8'	433.8'
Event	Event	Event	Event	Event	Event	Event	Event	Event	Event	Event	Event
		2.3 Yr	2.9 Yr	3.5 Yr	4 Yr	4.6 Yr	5.8 Yr	8.6 Yr	12.5 Yr	17.7 Yr	22.9 Yr

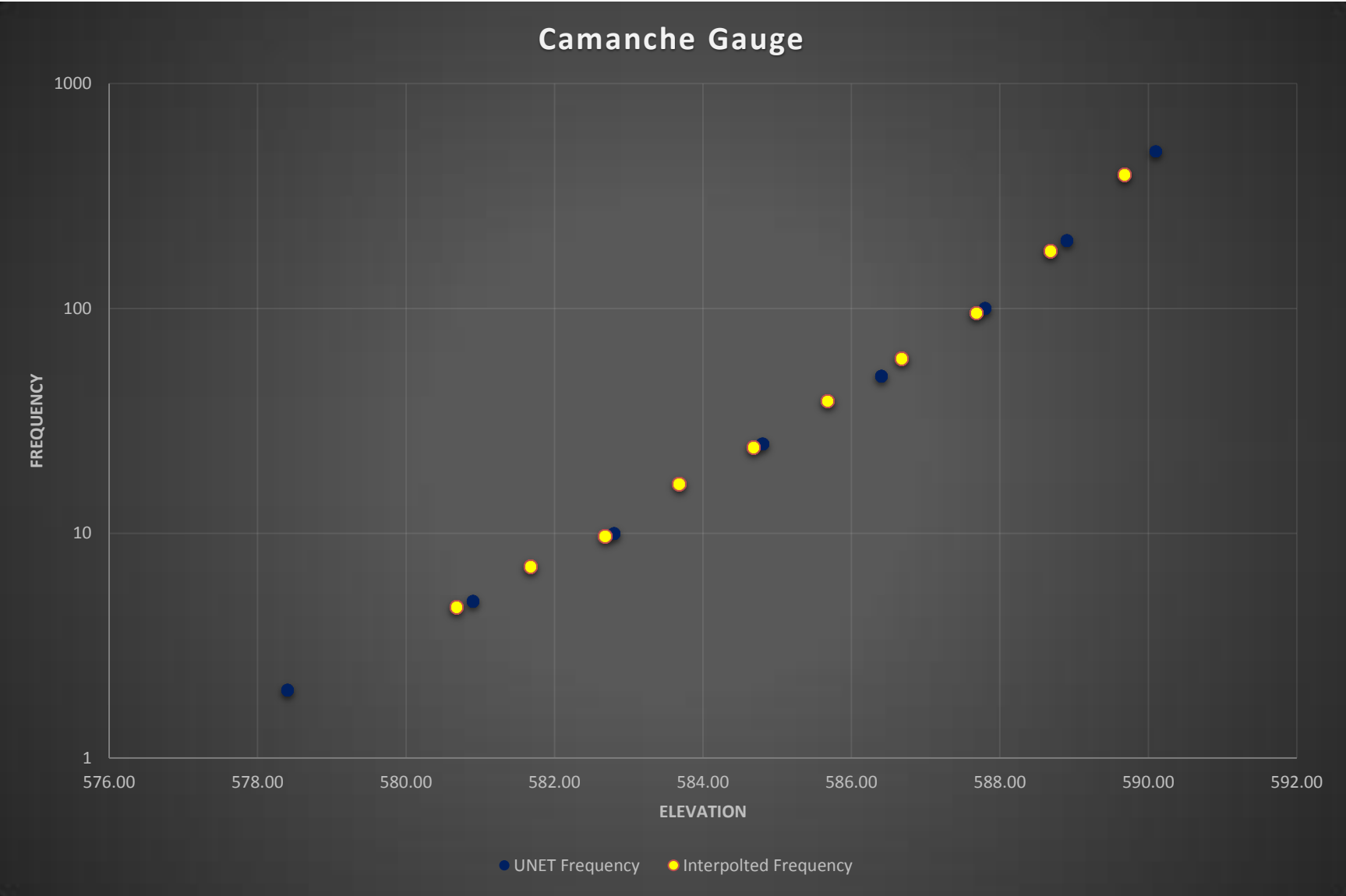
Stage 31'	Stage 32'	Stage 33'	Stage 34'	Stage 35'	Stage 36'	Stage 37'	Stage 38'	Stage 39'
Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev	Elev
434.8'	435.8'	436.8'	437.8'	438.8'	439.8'	440.8'	441.8'	442.8'
Event	Event	Event	Event	Event	Event	Event	Event	Event
30.9 Yr	40.9 Yr	52 Yr	73.7 Yr	95.4 Yr	135.9 Yr	181.4 Yr	298.3 Yr	465 Yr

Outside of 2-500 Year Flood Frequency Events

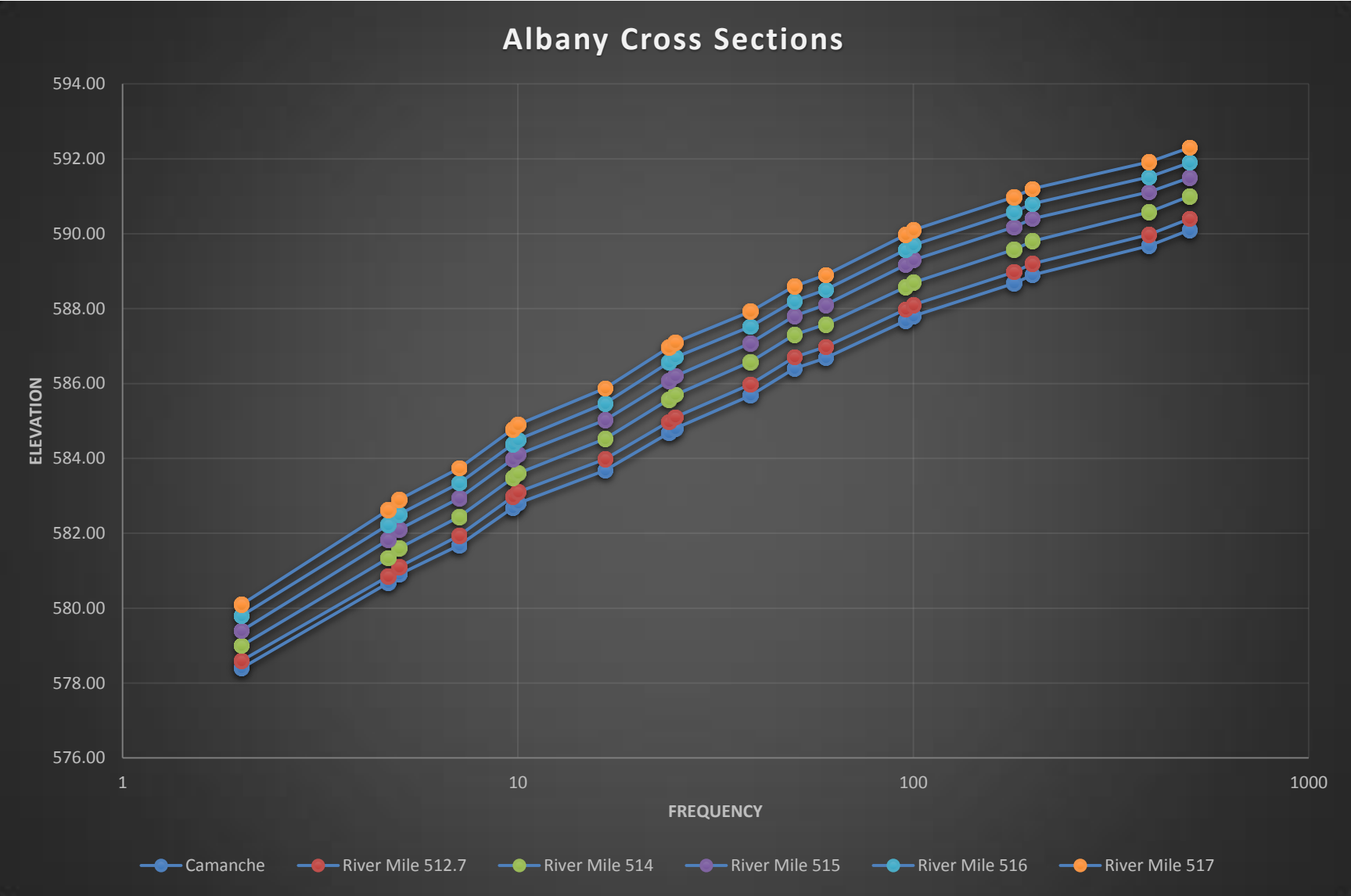
For UNET model cross sections located upstream and downstream from Grafton River Gauge at river mile 218.02, conversion of stage flood frequency event (year) to elevation (NGVD29) based on UNET Model Flood Profiles

X-Sect River Mile	Stage 21 Elevation (feet)	Stage 22 Elevation (feet)	Stage 23 Elevation (feet)	Stage 24 Elevation (feet)	Stage 25 Elevation (feet)	Stage 26 Elevation (feet)	Stage 27 Elevation (feet)	Stage 28 Elevation (feet)	Stage 29 Elevation (feet)	Stage 30 Elevation (feet)
212.38	423.4	424.4	425.4	426.2	427.2	428.3	429.5	430.6	431.7	432.8
213.87	423.8	424.8	425.8	426.6	427.6	428.6	429.8	430.9	432.0	433.1
215.09	424.0	425.1	426.1	427.0	428.0	429.0	430.1	431.2	432.2	433.3
216.55	424.4	425.5	426.5	427.4	428.4	429.4	430.5	431.5	432.5	433.5
RG 218.02	424.8	425.8	426.8	427.8	428.8	429.8	430.8	431.8	432.8	433.8
218.86	425.1	426.2	427.2	428.1	429.1	430.1	431.1	432.1	433.1	434.1
220.02	425.7	426.7	427.8	428.6	429.6	430.6	431.5	432.5	433.5	434.5
221.05	426.3	427.3	428.3	429.1	430.0	431.0	431.9	432.9	433.8	434.8

# Gauge Elevation to Frequency

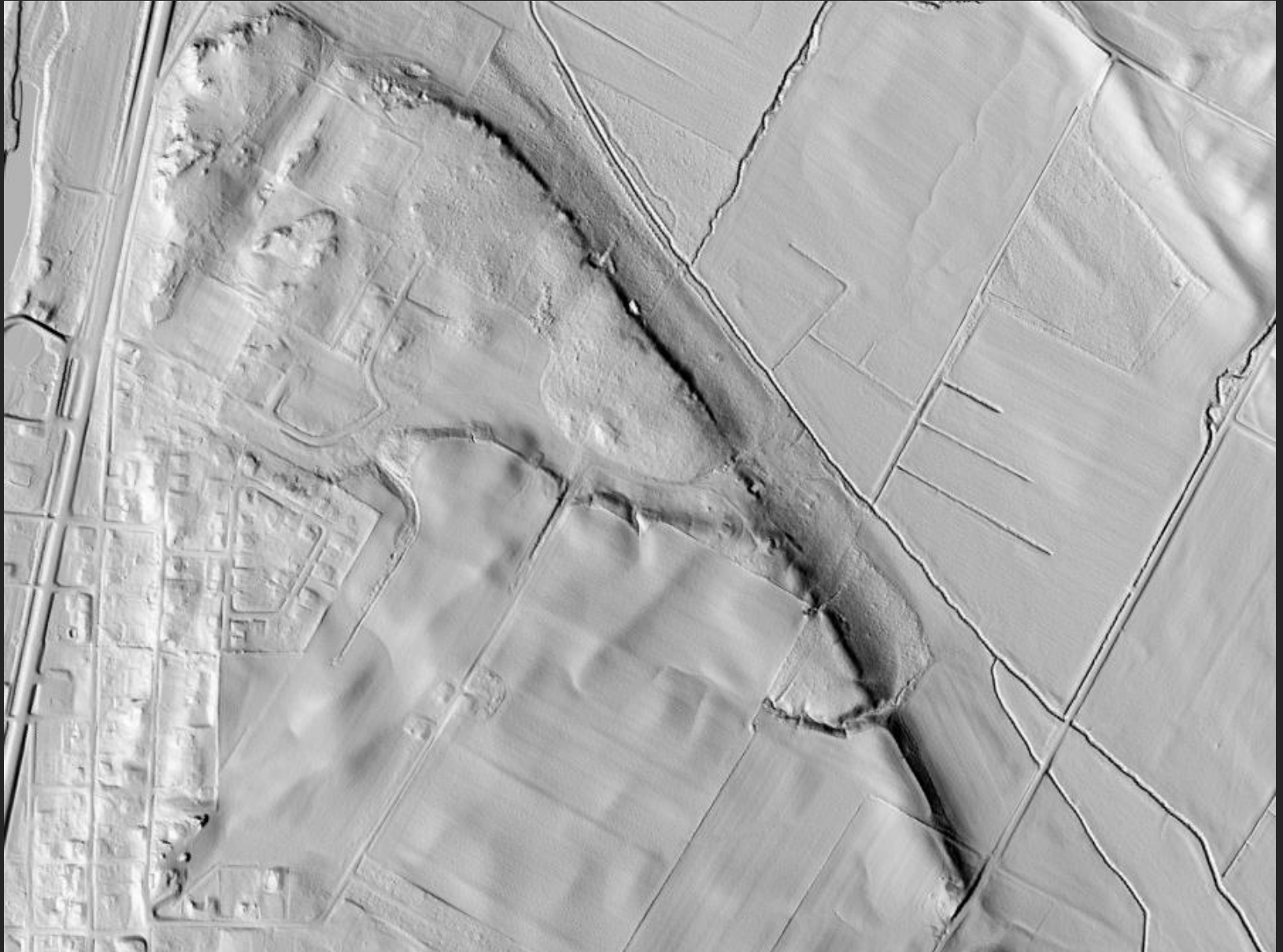


# Frequency to Elevation at Model Cross Sections





# LiDAR DEM



## Light Detection And Ranging

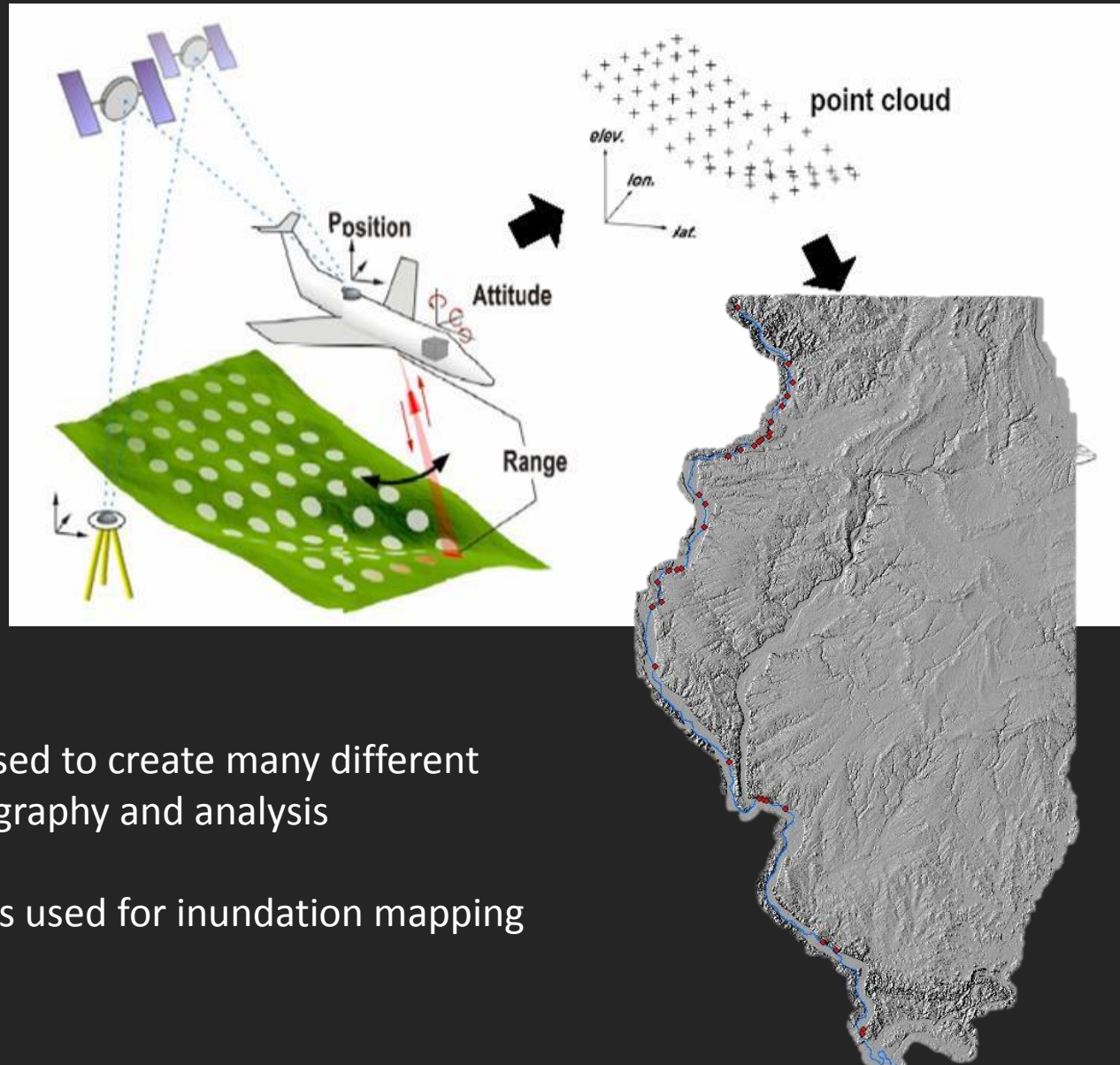
Typically airborne, position and speed data are collected while laser pulses measure the distance to the earth below.

This process results in a point cloud with (x,y,z) coordinates with centimeter-level accuracy for (x,y) coordinates and z values accurate to within 6 inches.

LiDAR point clouds can be used to create many different elevation products for cartography and analysis

Bare earth digital elevation is used for inundation mapping

## What is LiDAR?



# Calculating Inundation



UNET modeled water surface



LiDAR Digital Elevation Model



## Inundation Depth

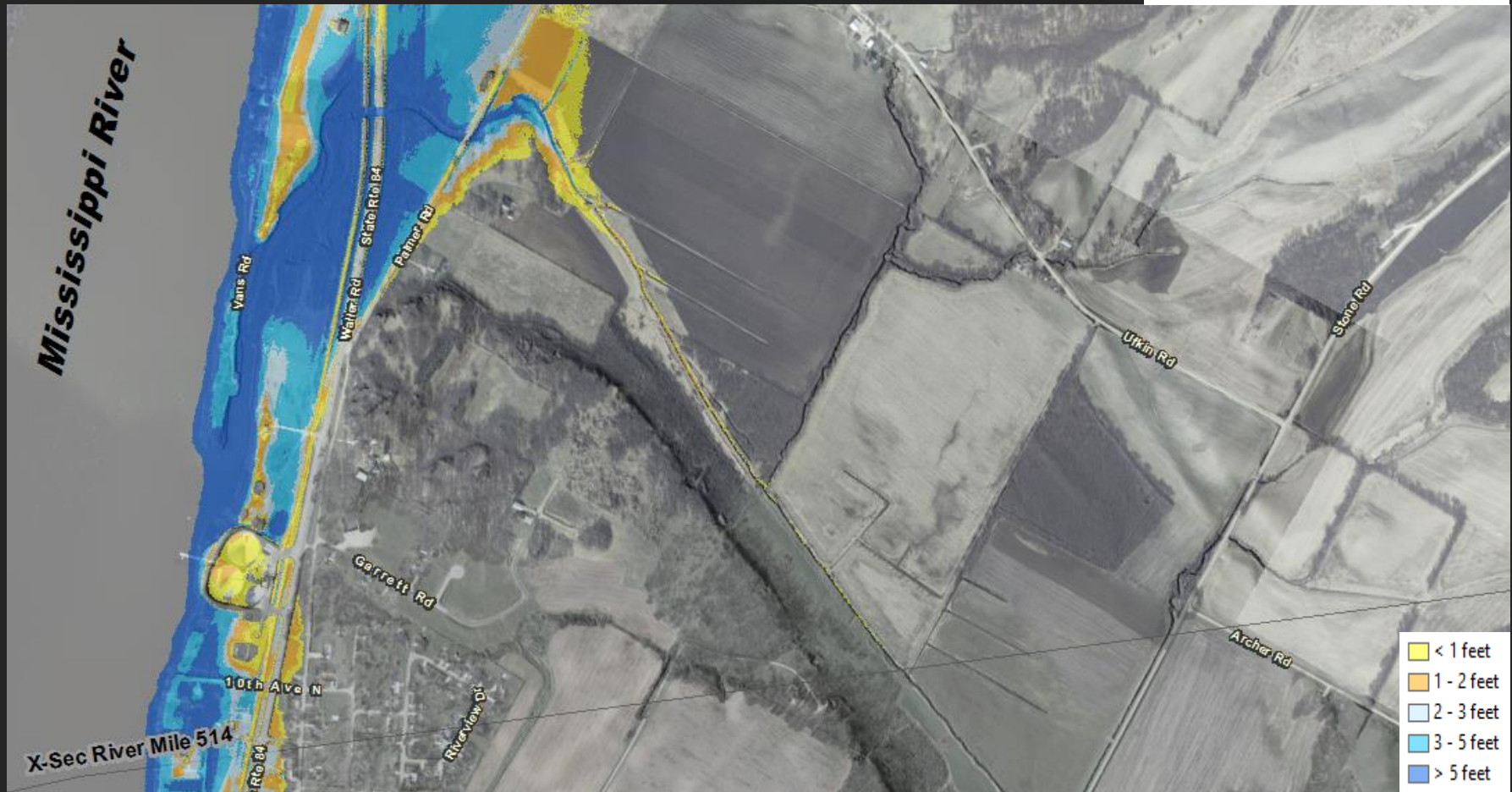


Inundation layer displays extent and depth of flooding for a flood stage at a nearby gauge

Depth can be categorized for emergency planning and response

Increasing stages show changes in flooding depth and extent

## Albany Stage 22 at Camanche Gauge



# Albany Stage 25 at Camanche Gauge



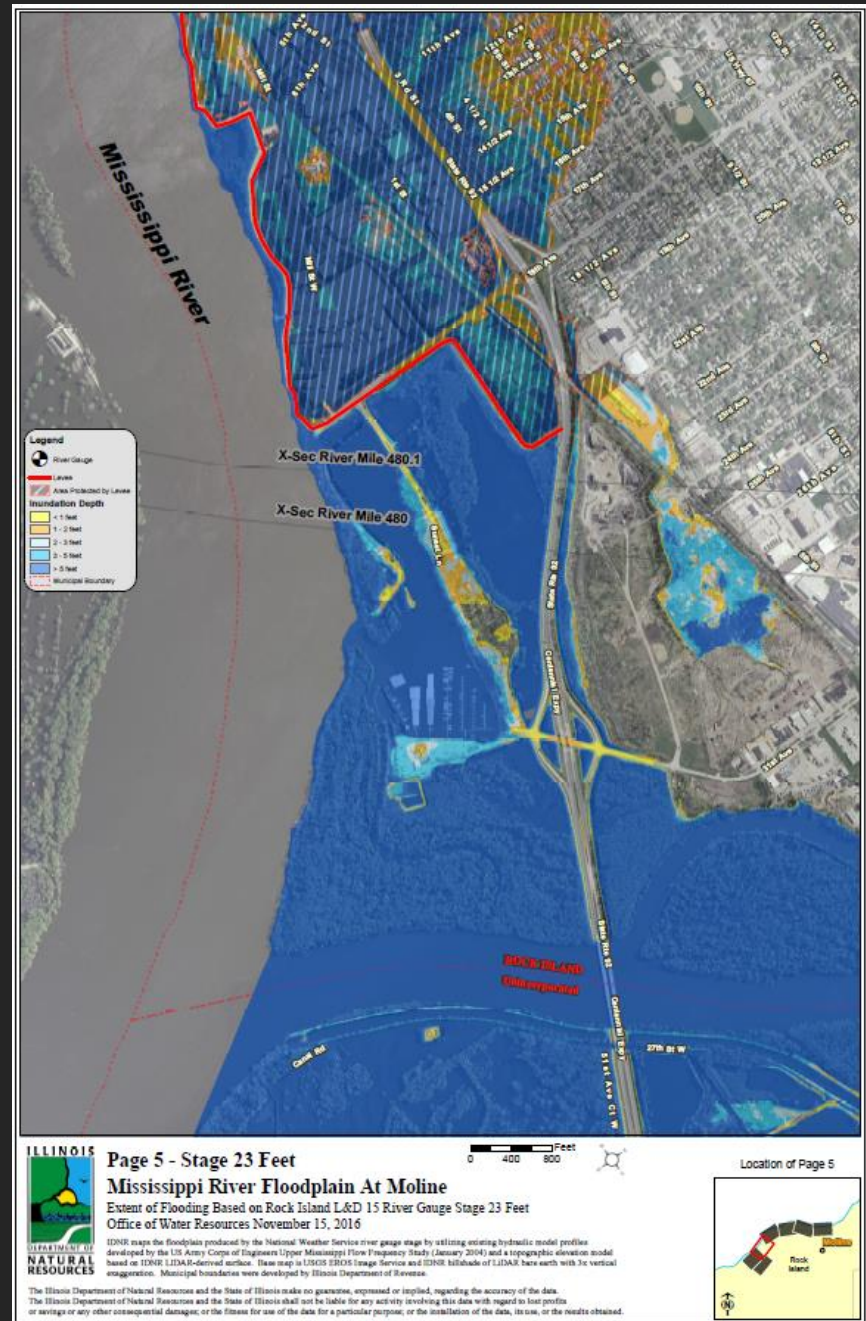


# Albany Stage 27 at Camanche Gauge

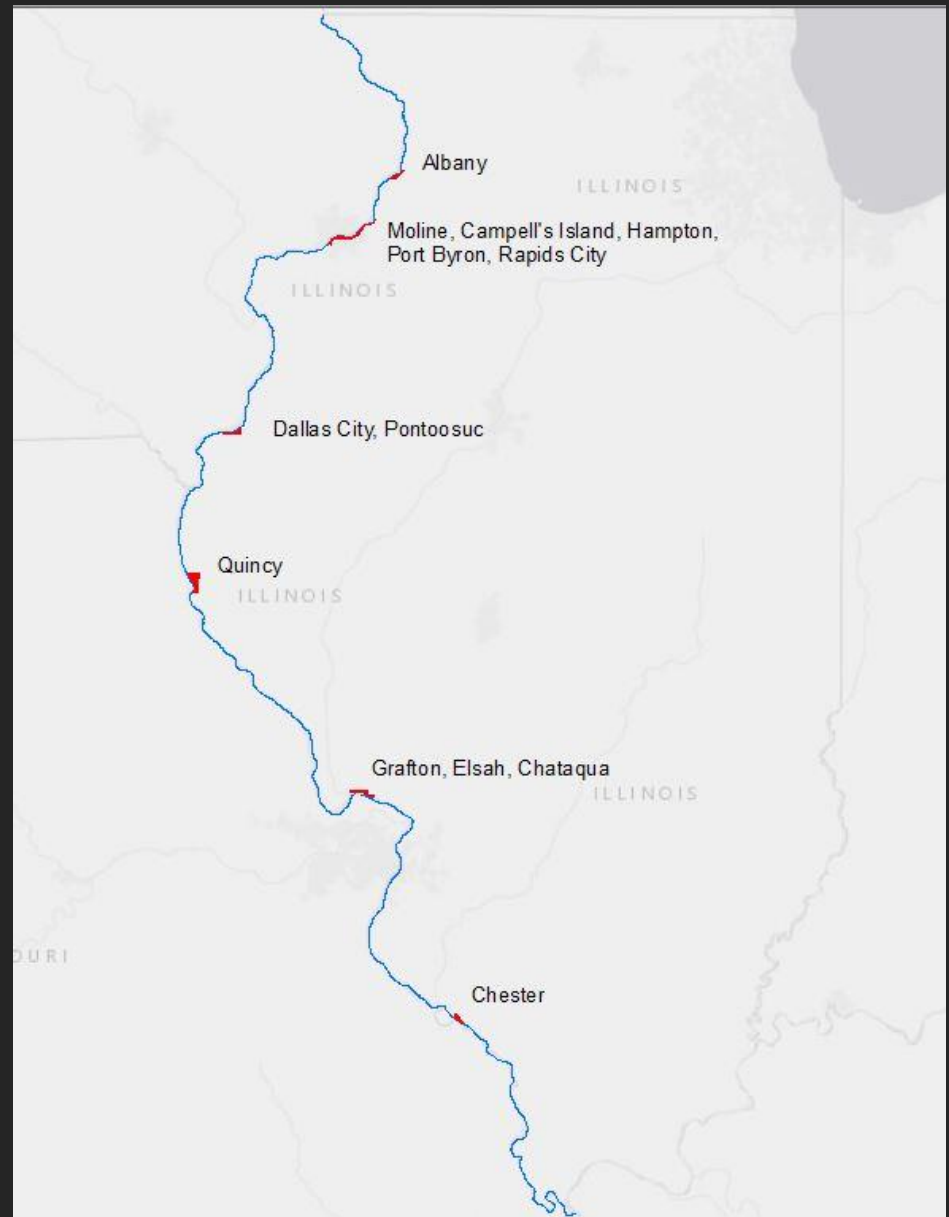


# Preparing for Distribution

- Road labels & municipal boundaries
- Gauges & UNET cross sections
- Levee & reduced risk areas
- EROS high resolution orthoimagery
- Detailed metadata made for each community



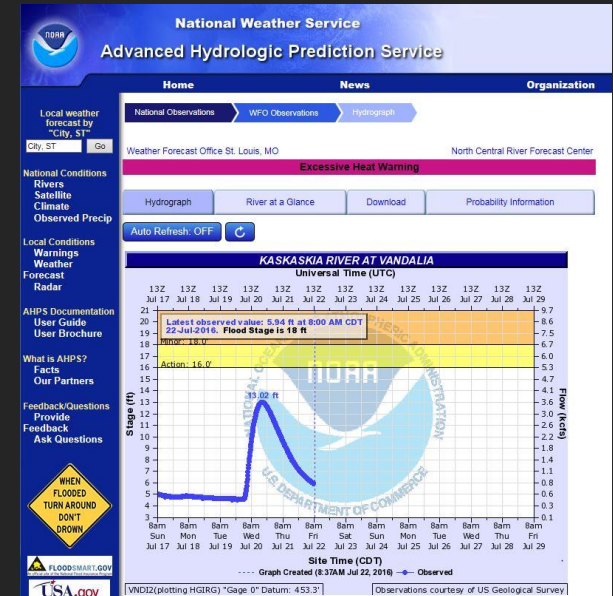
- Stage Inundation Library created for 13 communities
- Approximately 100 stage inundation rasters created





# Mapping Validation

- 38.5 Illinois Route 3 at Rockwood and Missouri Highway J just west of Highway 61 between Ste. Genevieve and St. Marys begin flooding near this height.
- 38.4 At this level IL Route 3 at levee east of Cora inundated.
- 38.1 Near this level, Illinois Route 3 near the Mary's River bridge is closed.
- 37.7 Near this height, Route J is closed in both directions at U.S. Highway 61.
- 37.6 At this height, Missouri Route M between Route H and Perry County Road 924 is closed.
- 37.5 The southbound lane on Kaskaskia Street and the south parking lot at Menard Correctional Center begins flooding.
- 37.2 Near this height, U.S. Highway 61 is closed between Ste. Genevieve and Route J.
- 37 Union Pacific property along Water Street begins to flood.
- 36.9 Near this height, U.S. Highway 61 is closed from Route J to St. Mary.
- 36.5 Chester water intake house is flooded... damage begins to occur to 4 homes and administration buildings at Menard State Prison. Prairie DuRocher pump station damaged and road to Kaskaskia Lock inundated.
- 36 Chester water works pumphouse is threatened by flood waters. Highway 61 is closed at the bend at St. Marys and a detour is set up through town.
- 35.2 In Perry County, Highway C is closed between County Roads 352 and 354 (the Levee Road) near Menfro.
- 35 Ste. Genevieve flood gates are closed at this level.
- 34.79 Kaskaskia Street near the Menard Prison begins flooding near this height.
- 34.7 The north parking lot at Menard Correctional Center begins flooding.
- 33.5 Water Street in Chester begins flooding.
- 33 Within a foot of this height, Highway A is closed between County Roads 448 and 460 at Wittenberg in southern Perry County.

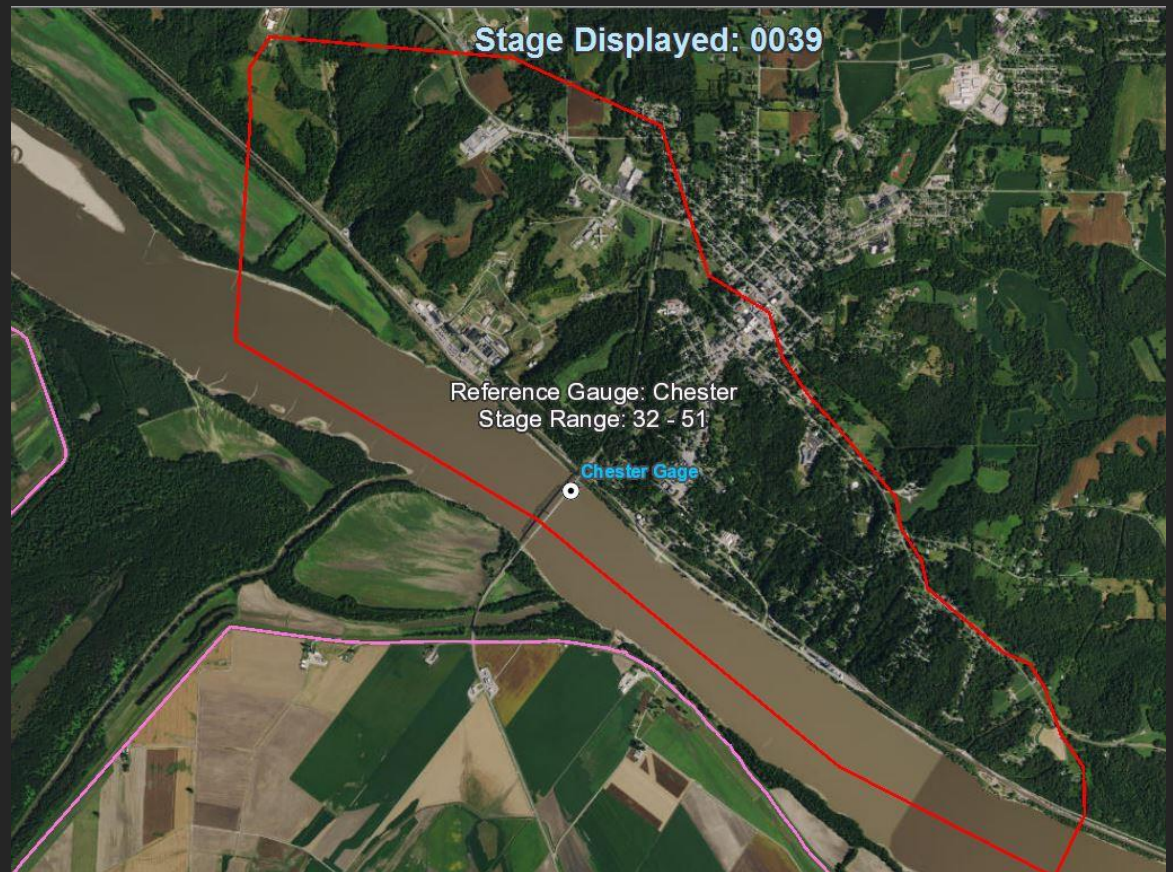


- Comparison to historical stage flood observations.
- Comparison to FEMA Flood Hazard Zone

# Chester

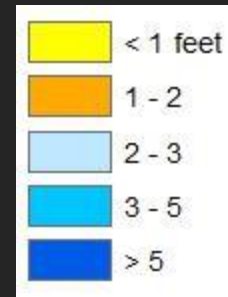
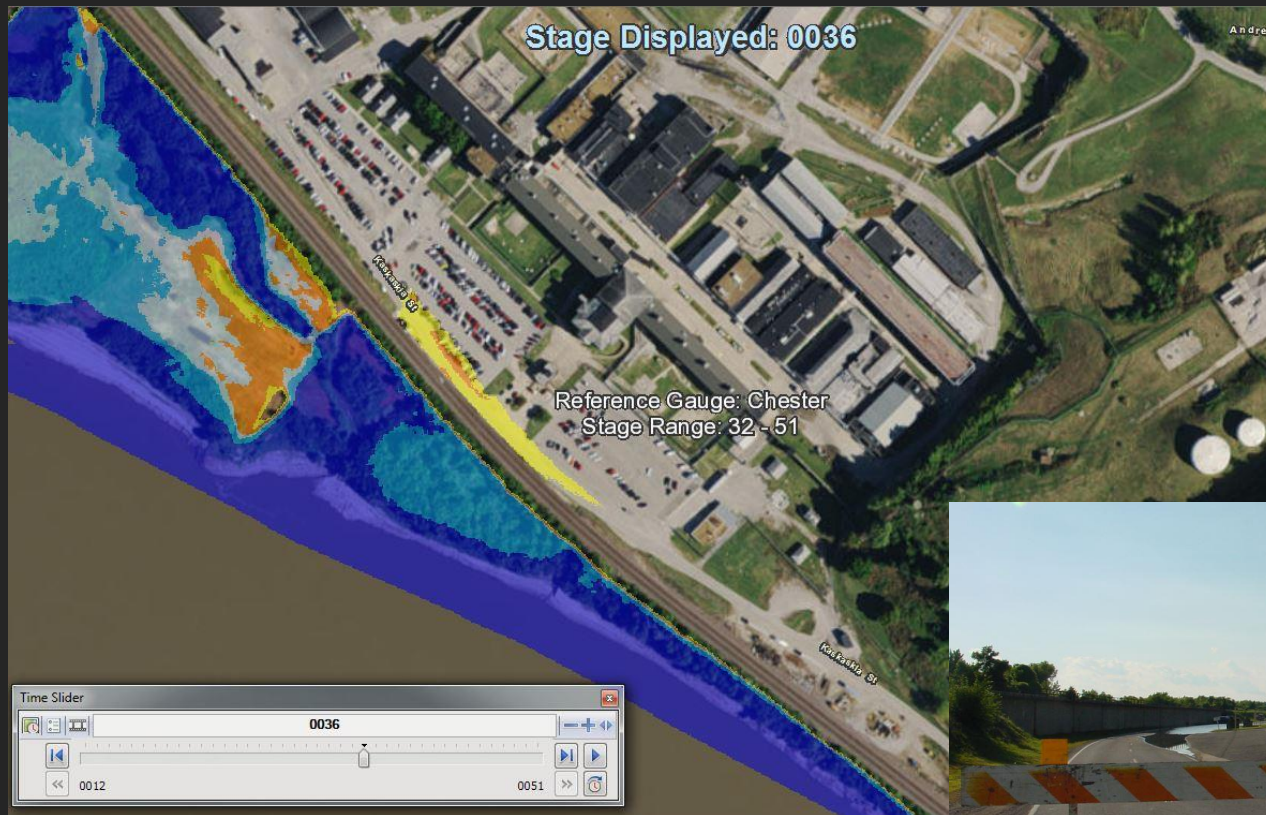
## Mapping Scenario

- River gauge in close proximity
- Mapped area no greater than 1.5 miles





# Chester

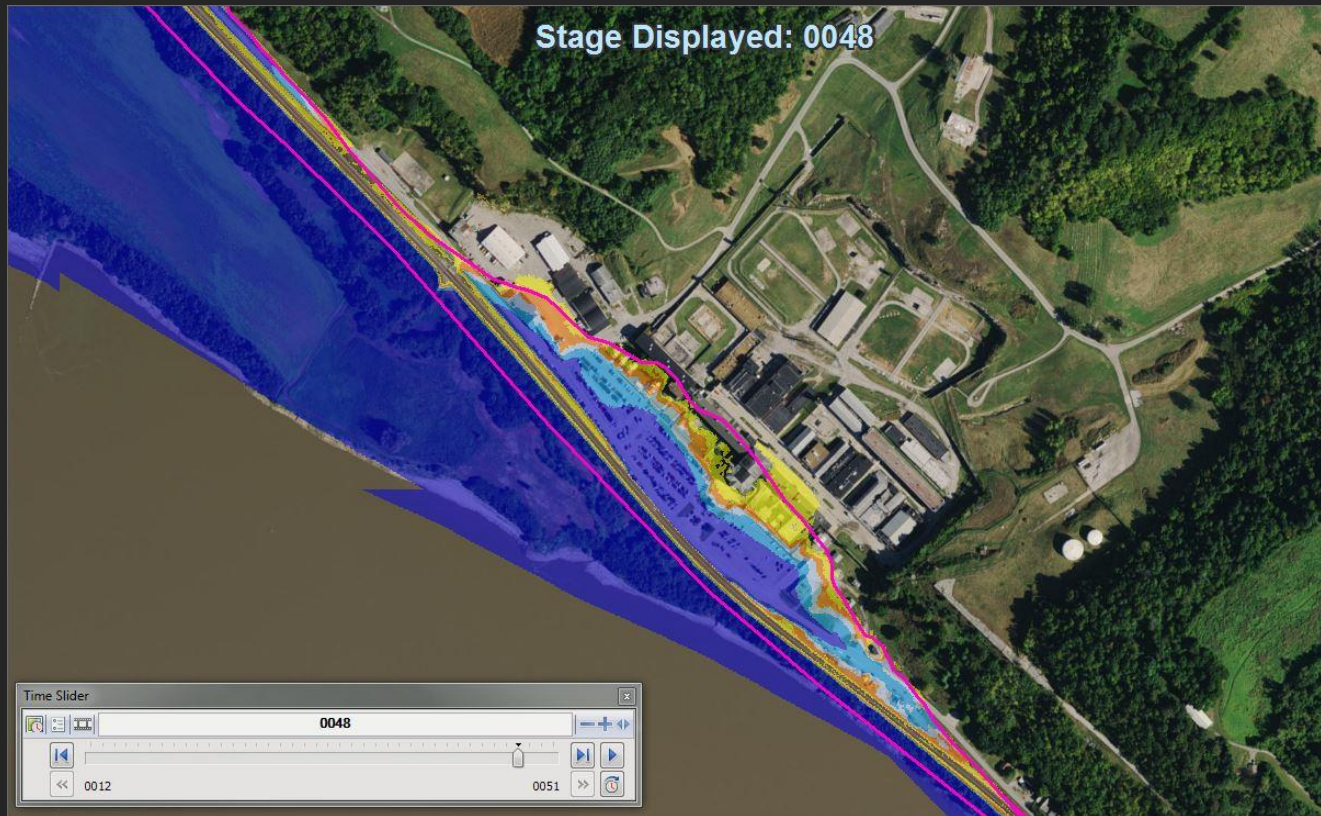


Stage 36.2 - Kaskaskia Road at Menard Correctional Center on June 28, 2010





# Chester



**Stage 48**  
102-Year Event  
Interpolated From  
UNET Model  
Profiles

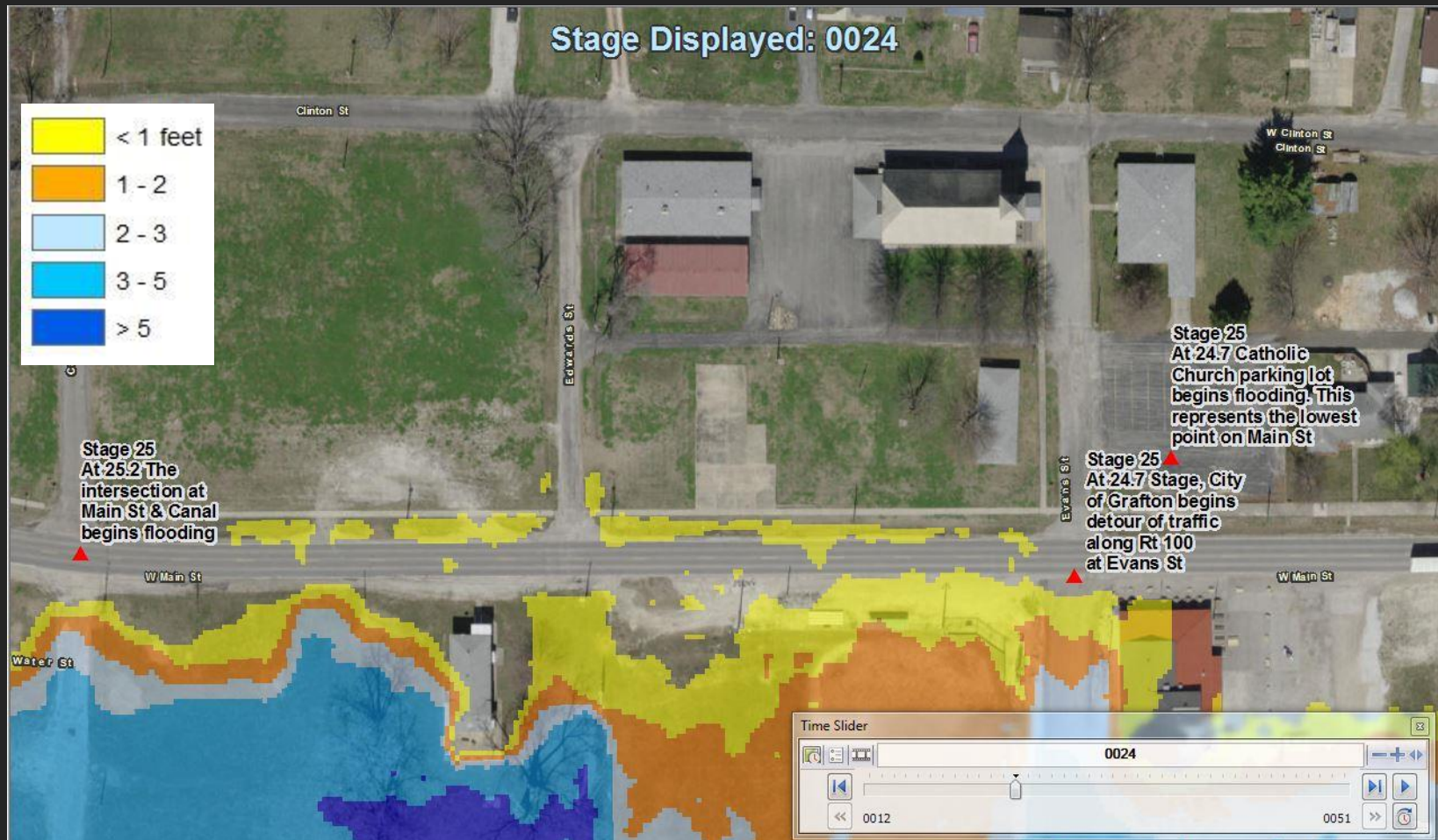
Mapped Stage  
Inundation  
Compares With  
FEMA 100-Year  
Flood Hazard Area





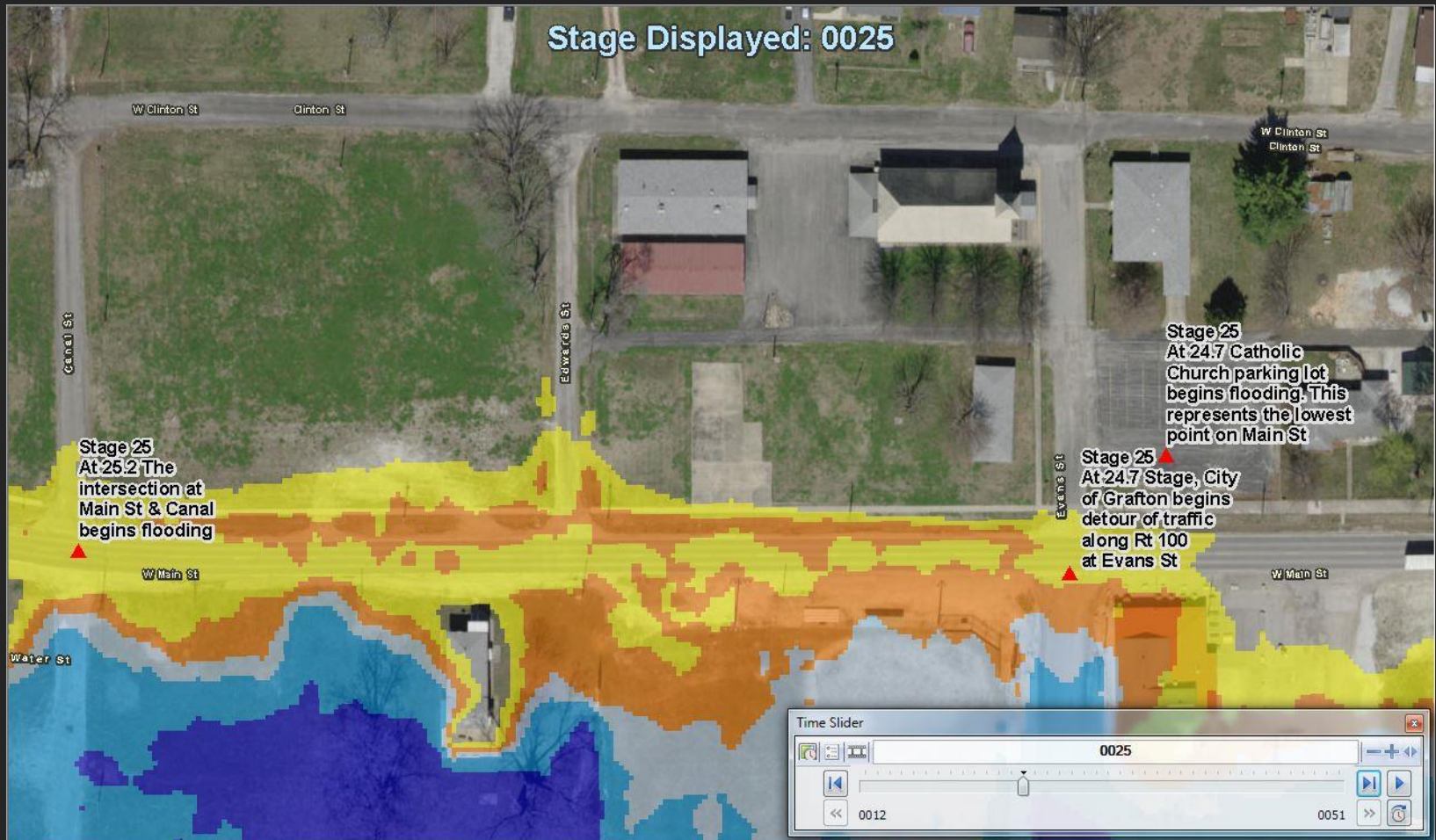
# Grafton

Close Proximity To Gauge



# Grafton

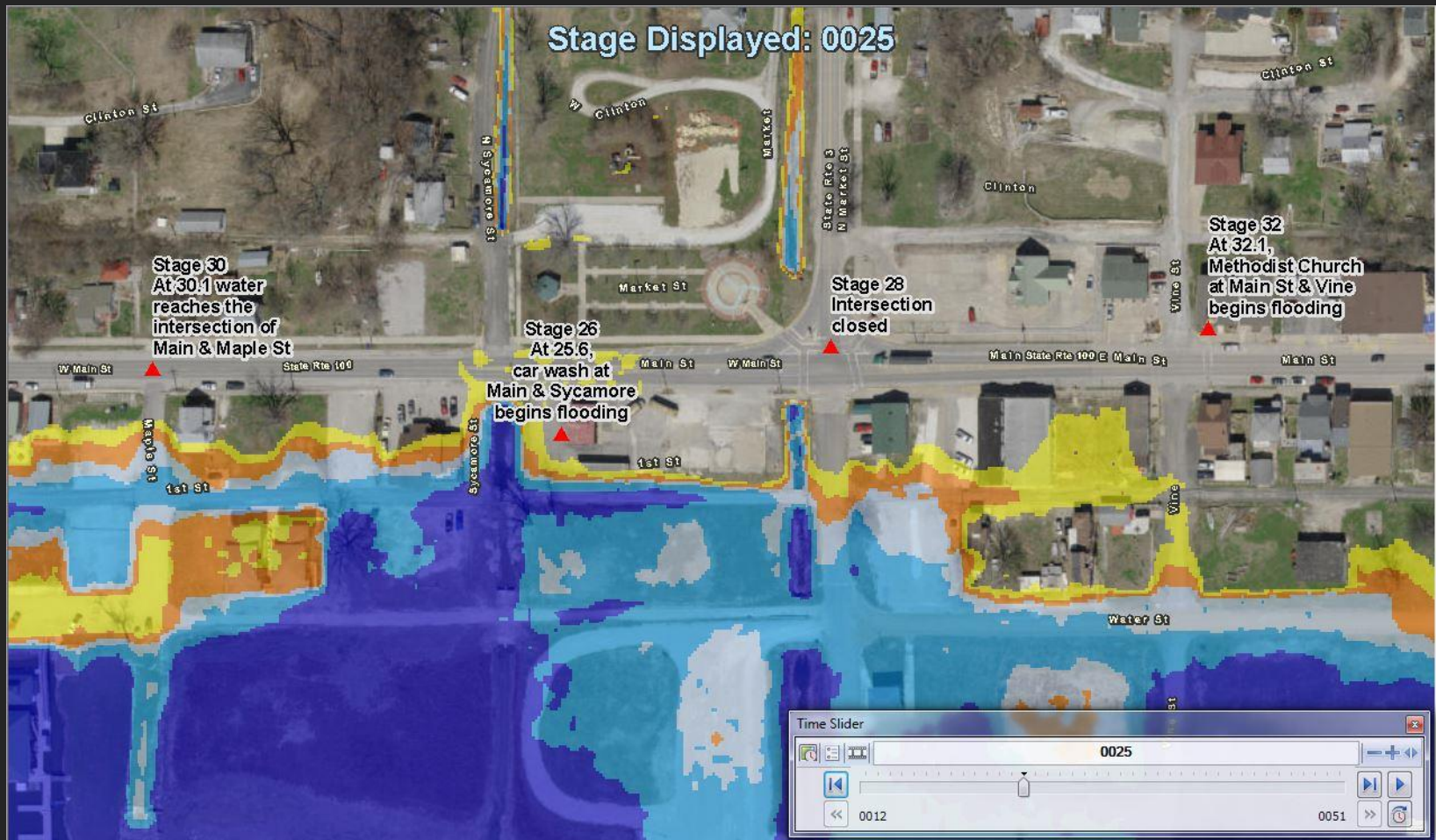
Close Proximity To Gauge





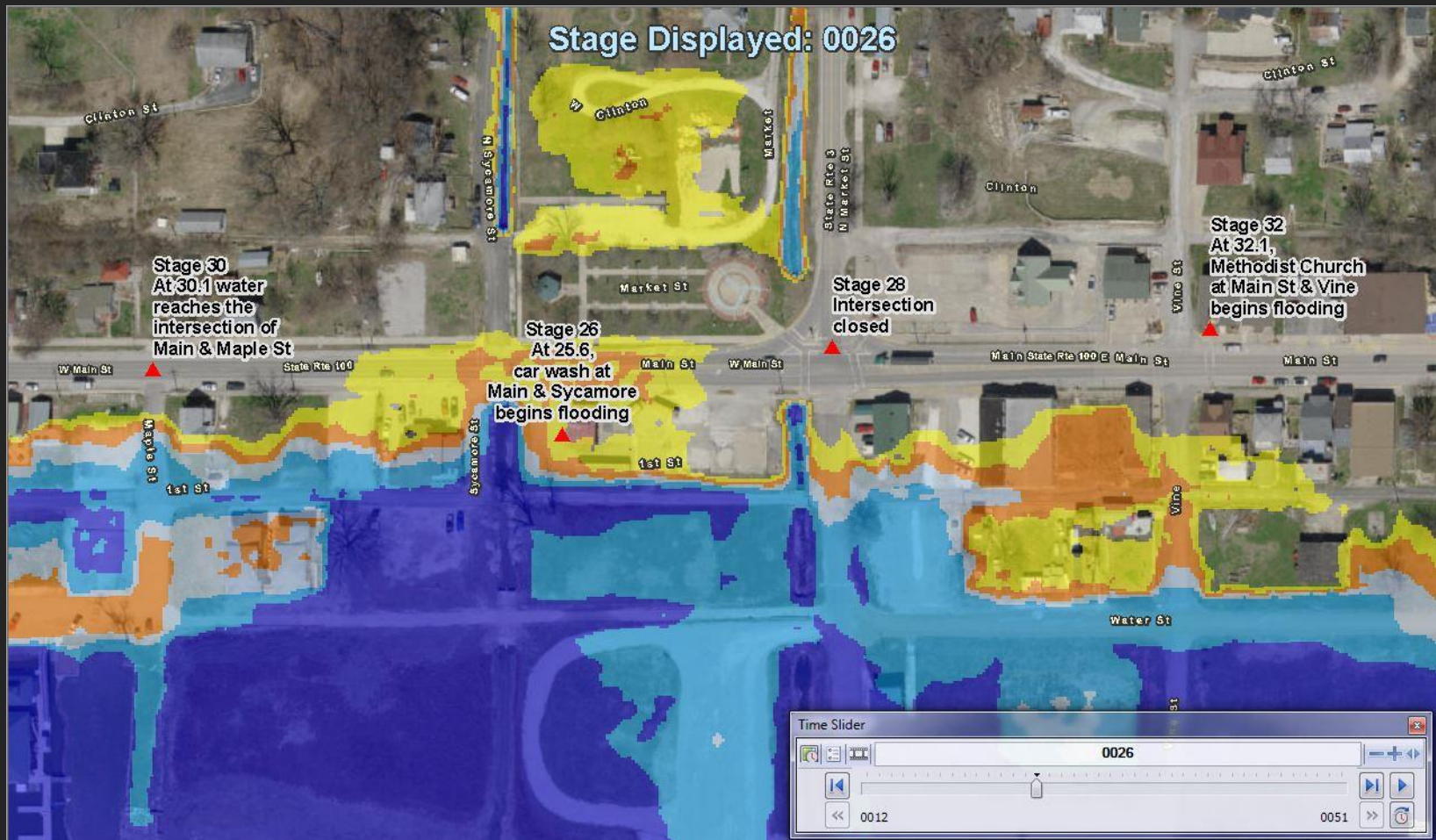
# Grafton

Close Proximity To Gauge



# Grafton

Close Proximity To Gauge





# Grafton

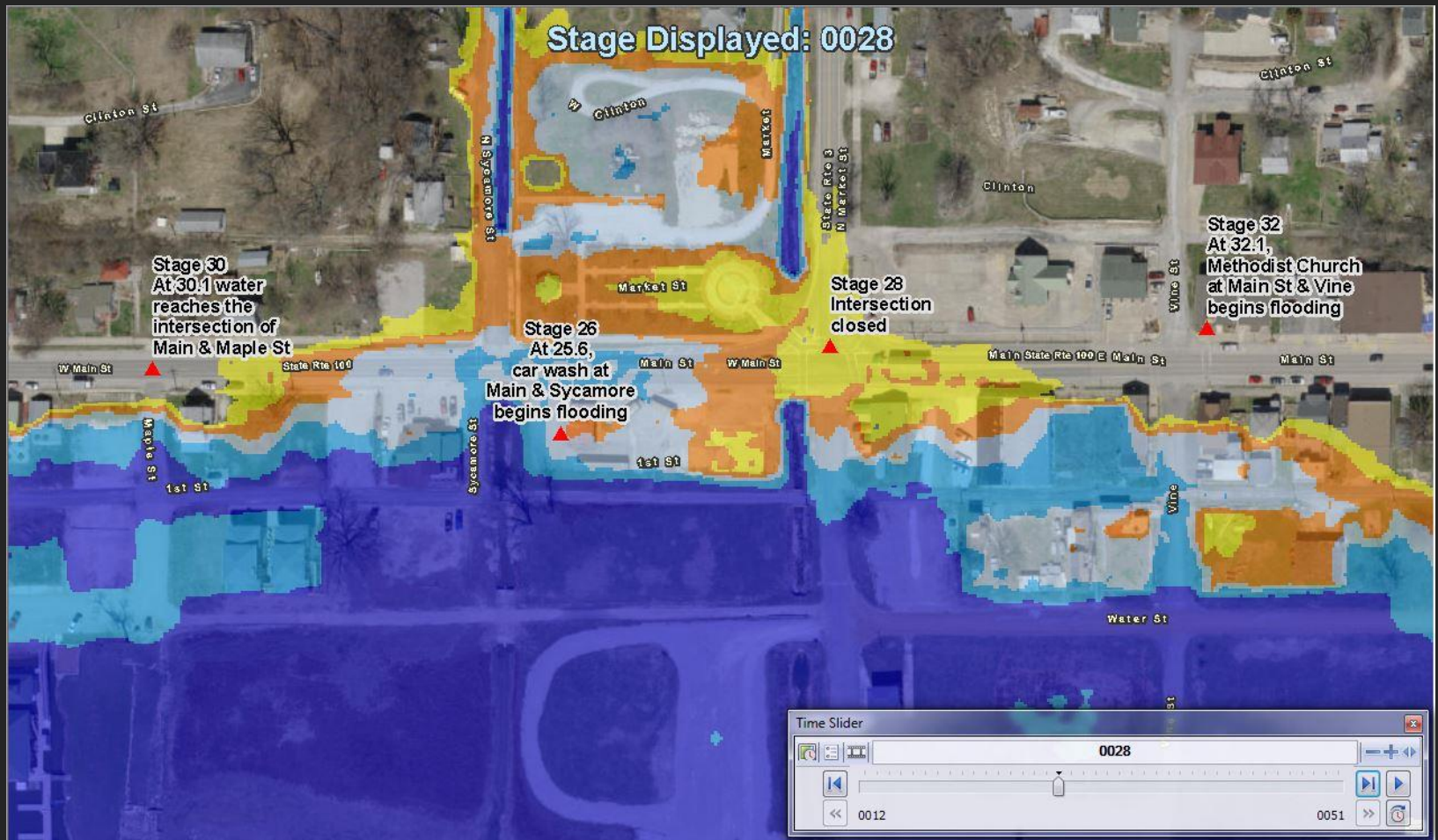
Close Proximity To Gauge





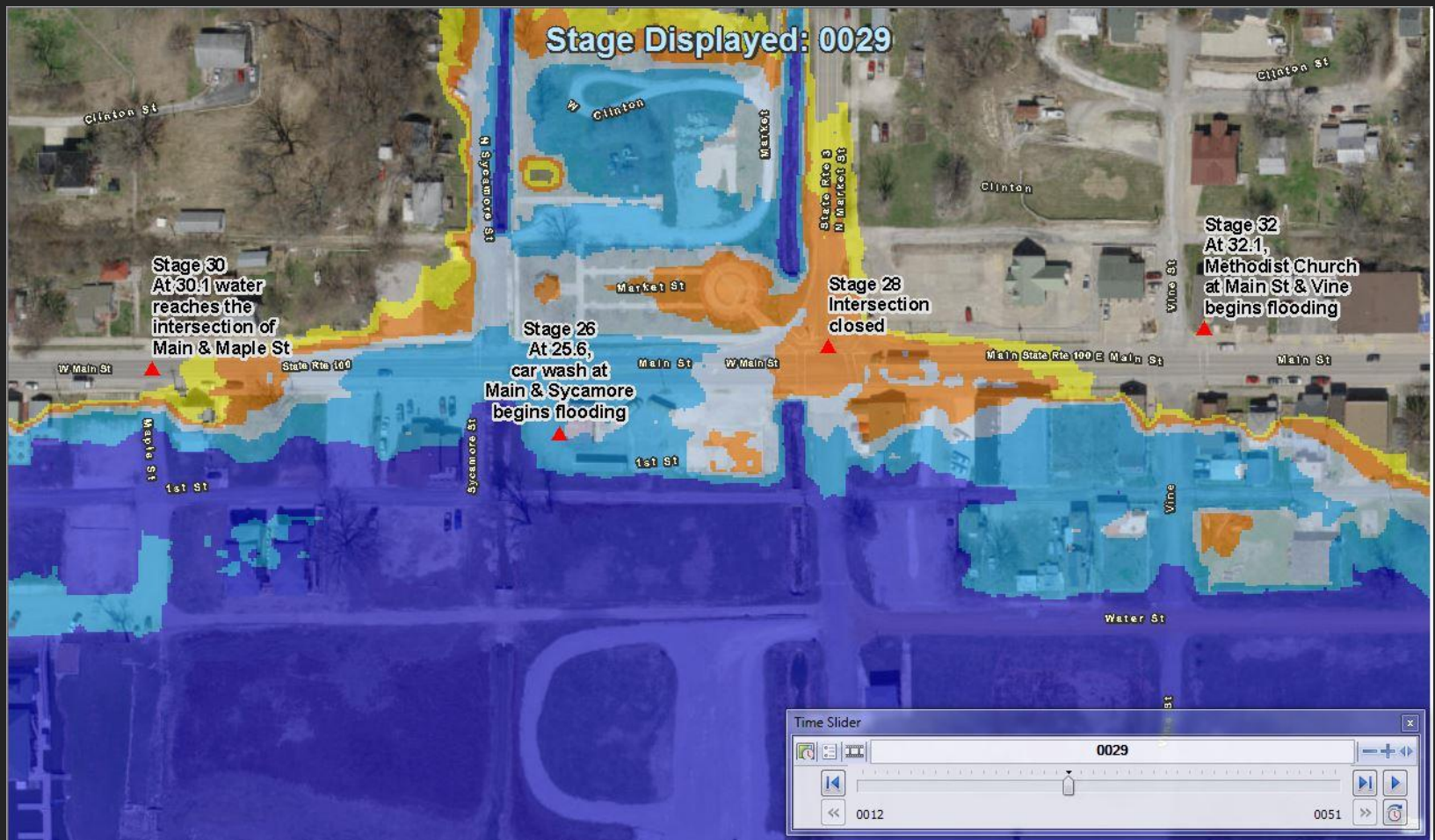
# Grafton

Close Proximity To Gauge



# Grafton

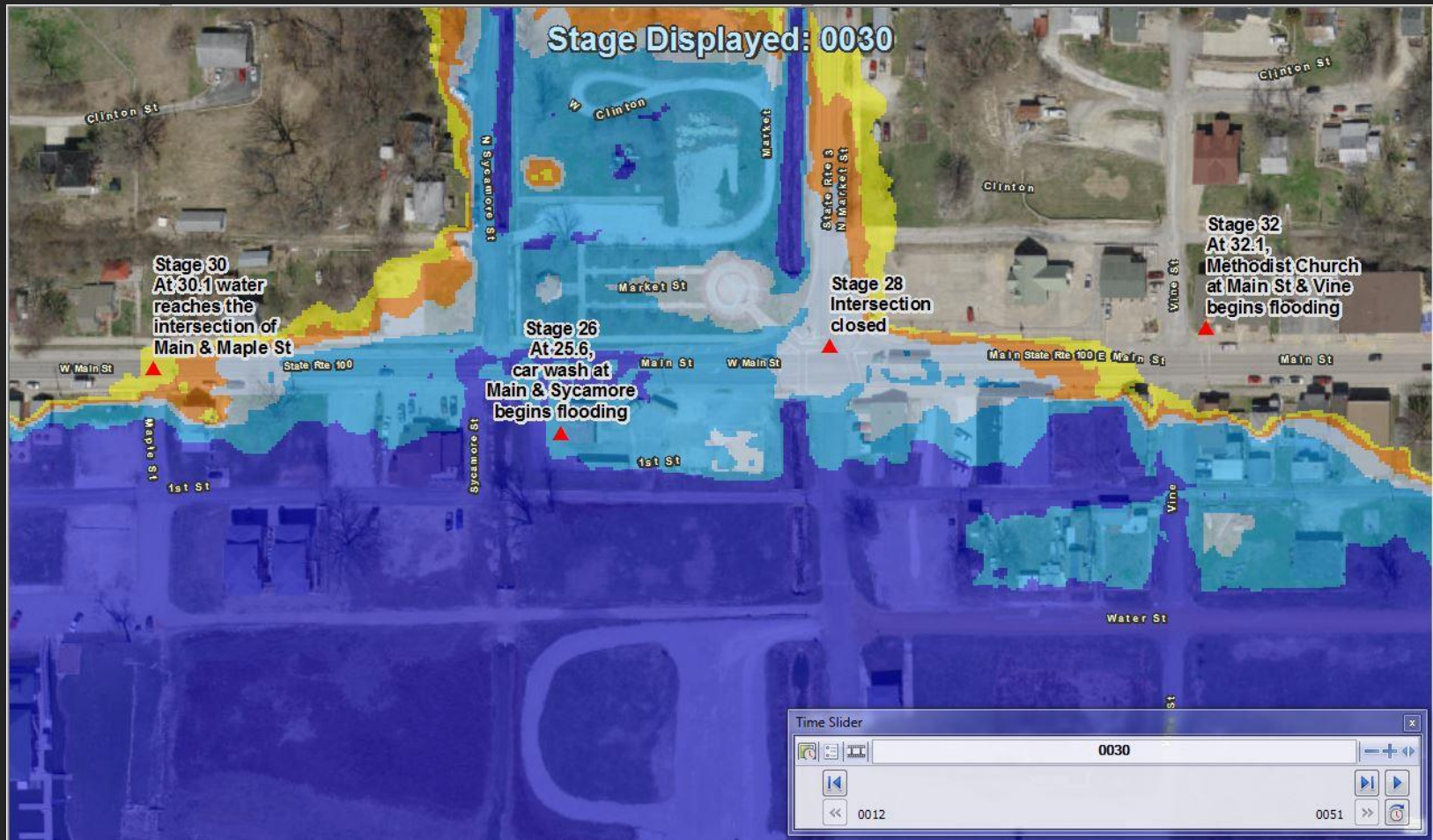
Close Proximity To Gauge





# Grafton

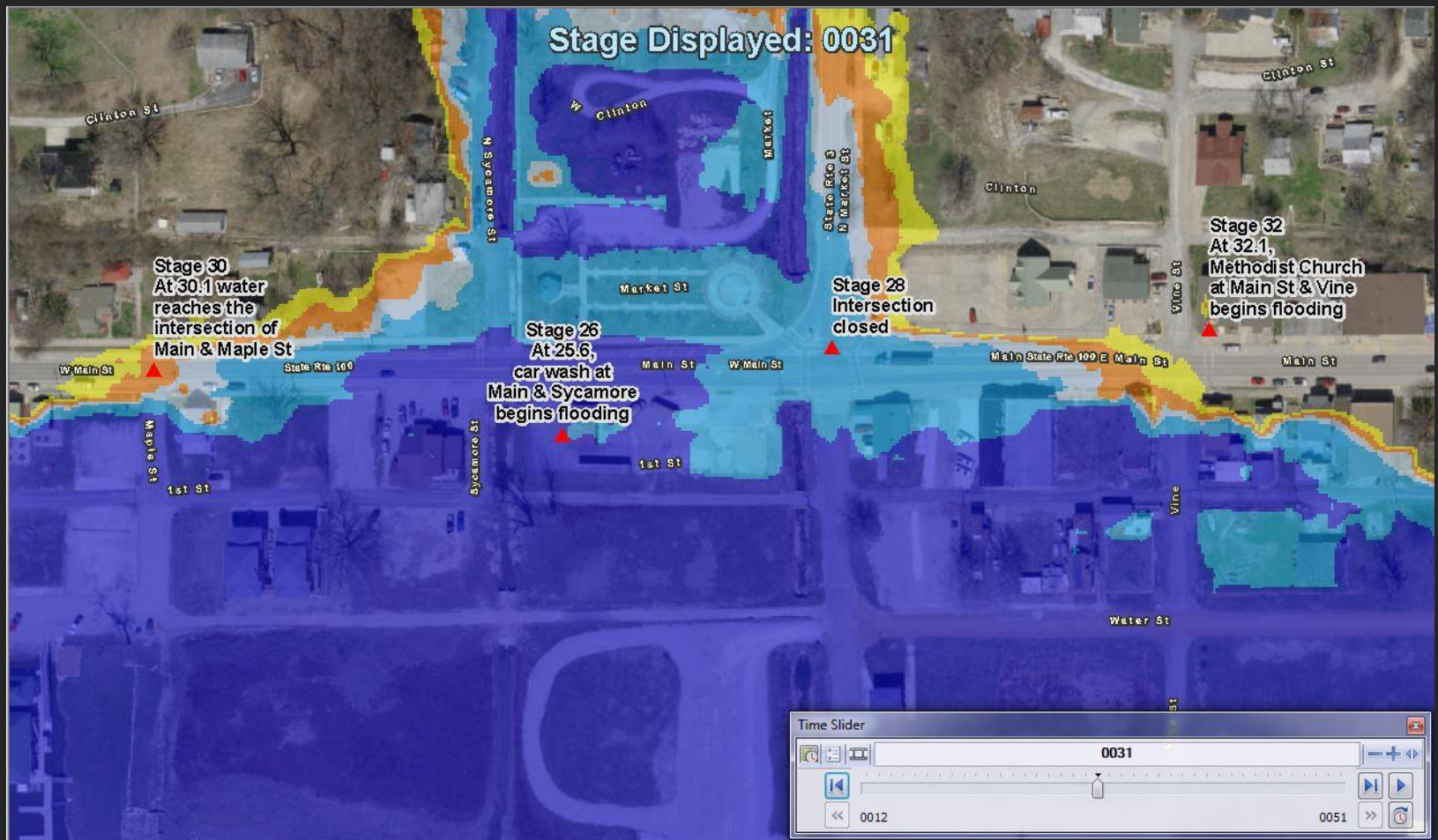
Close Proximity To Gauge





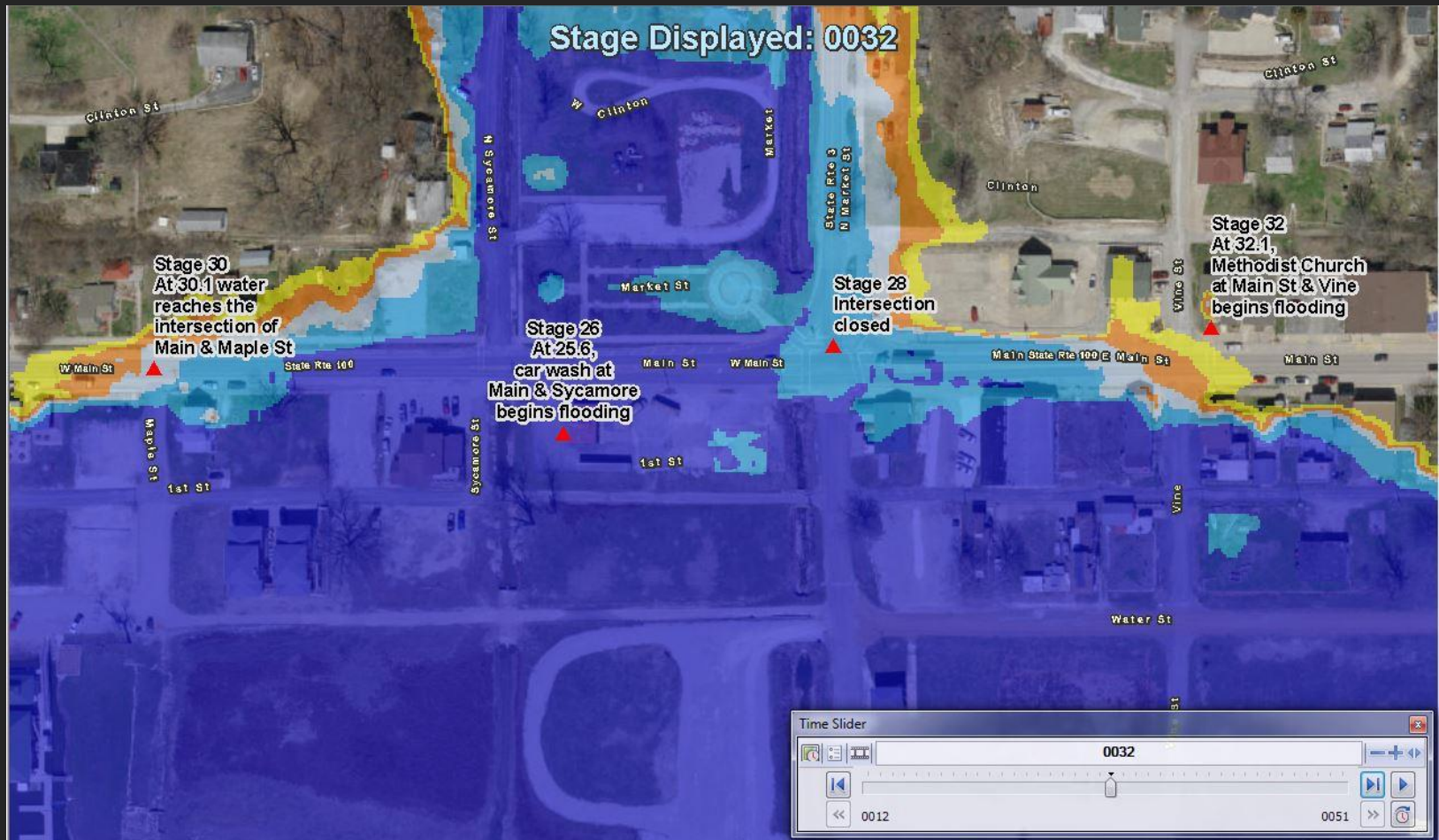
# Grafton

Close Proximity To Gauge



# Grafton

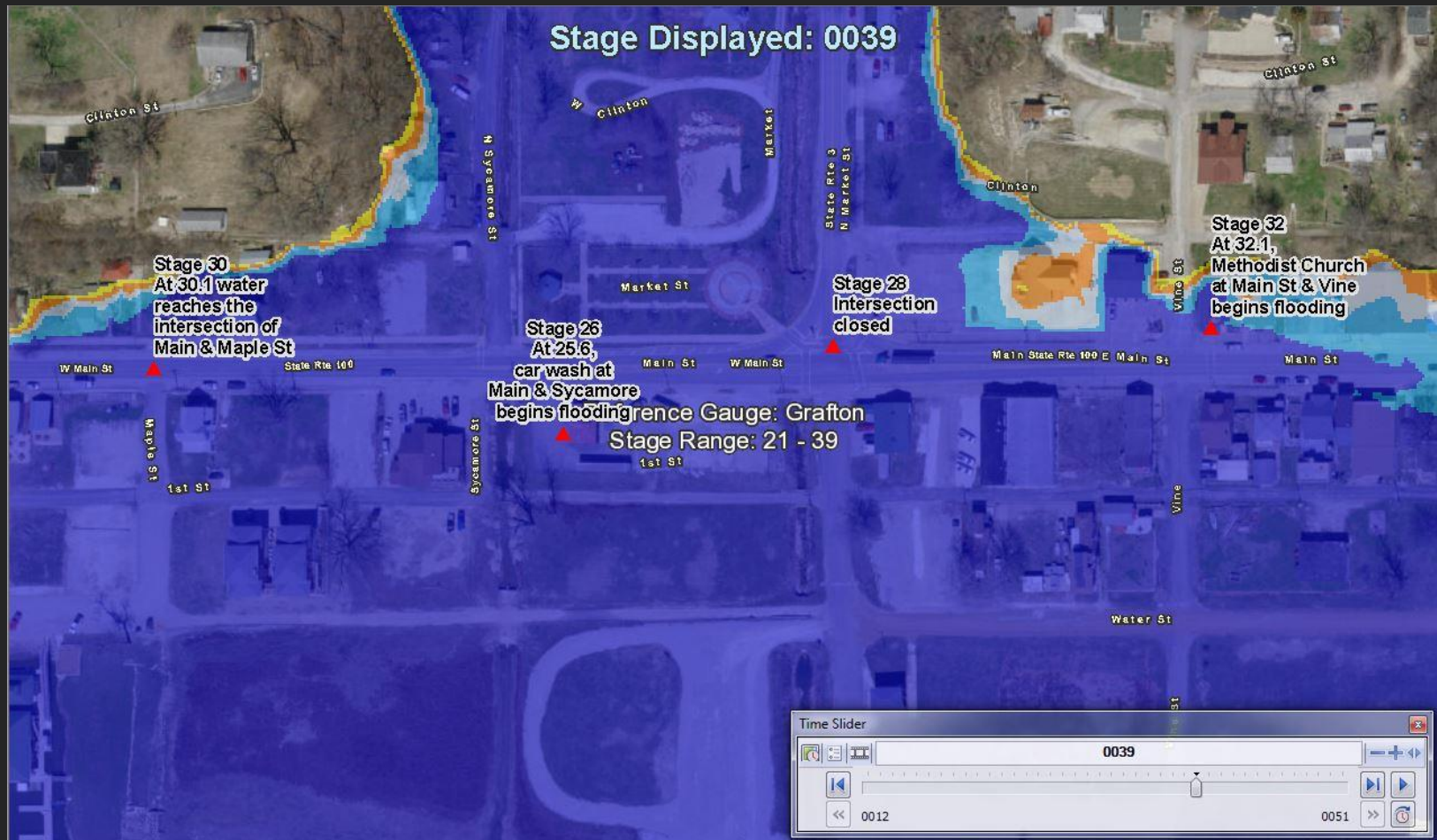
Close Proximity To Gauge





# Grafton

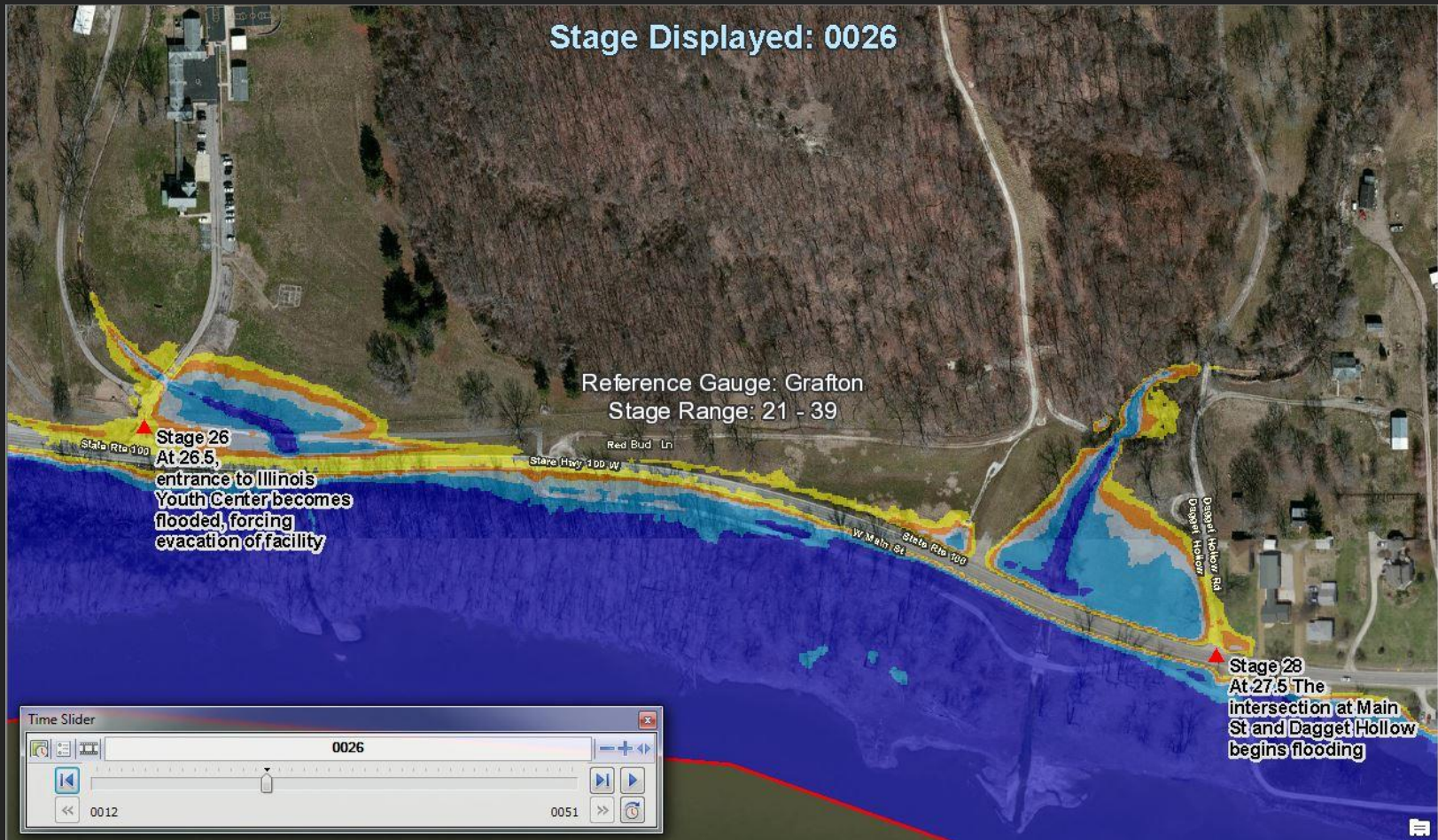
Close Proximity To Gauge





# Grafton

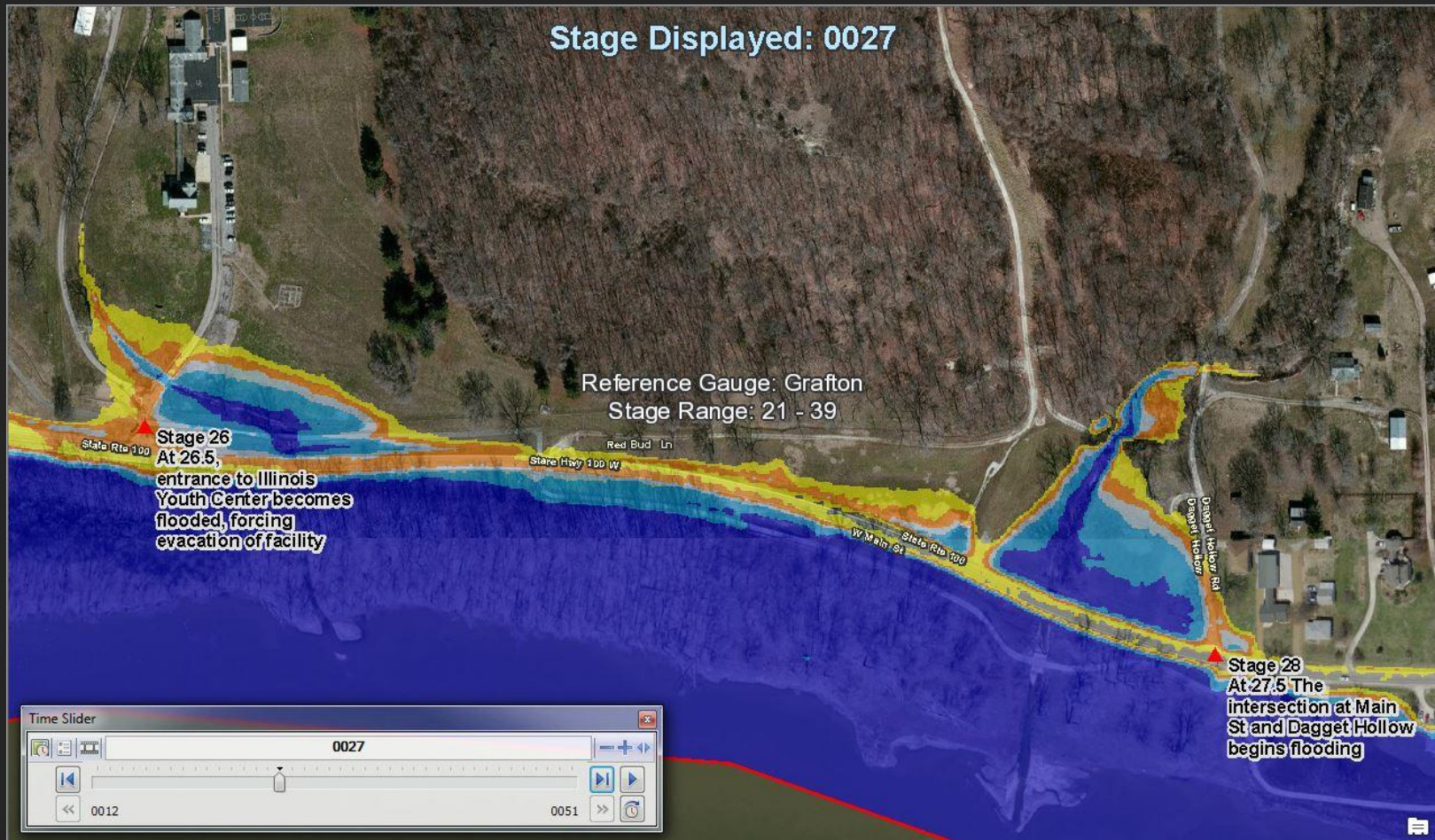
3 Miles West Of Gauge





# Grafton

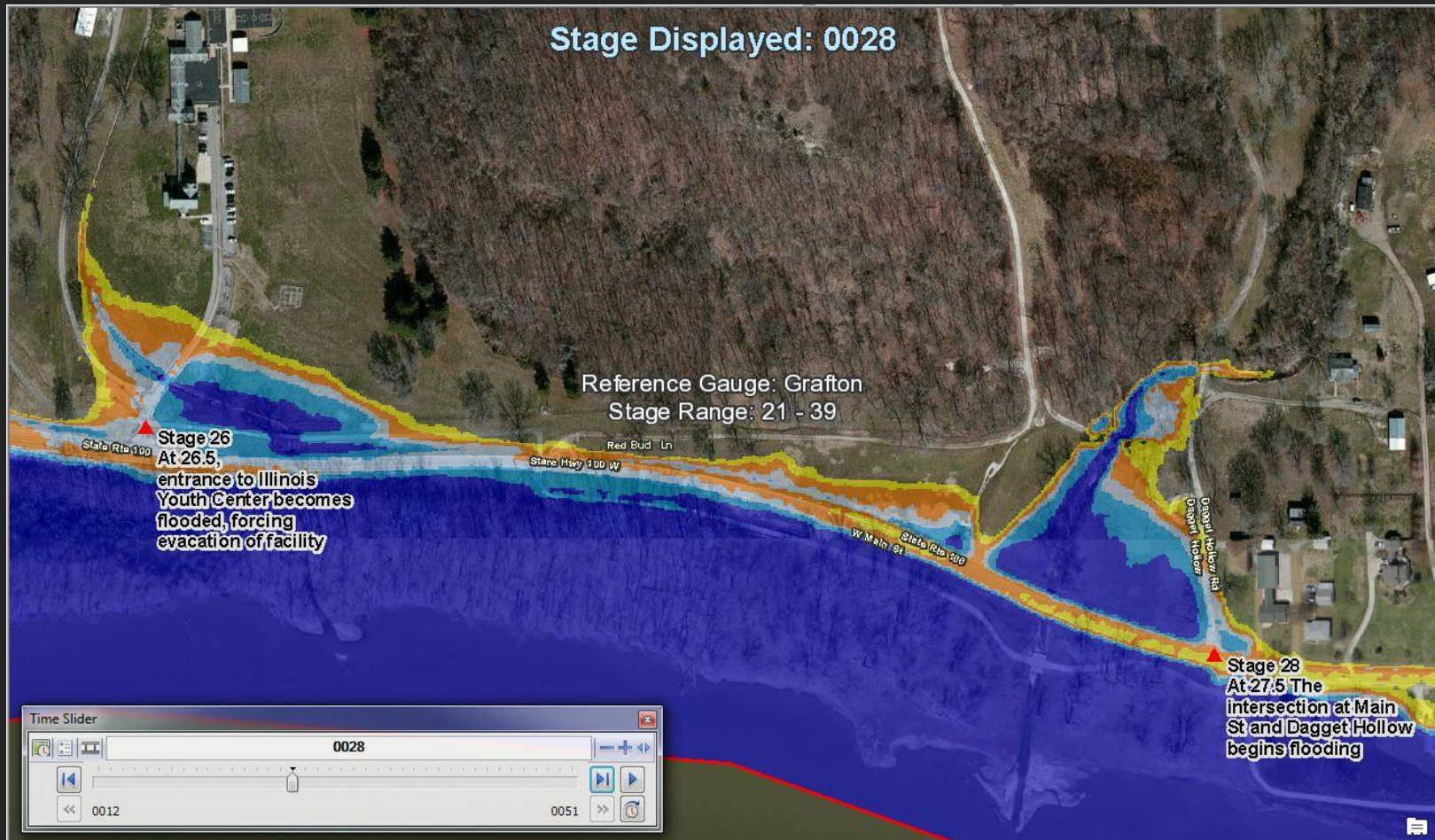
3 Miles West Of Gauge





# Grafton

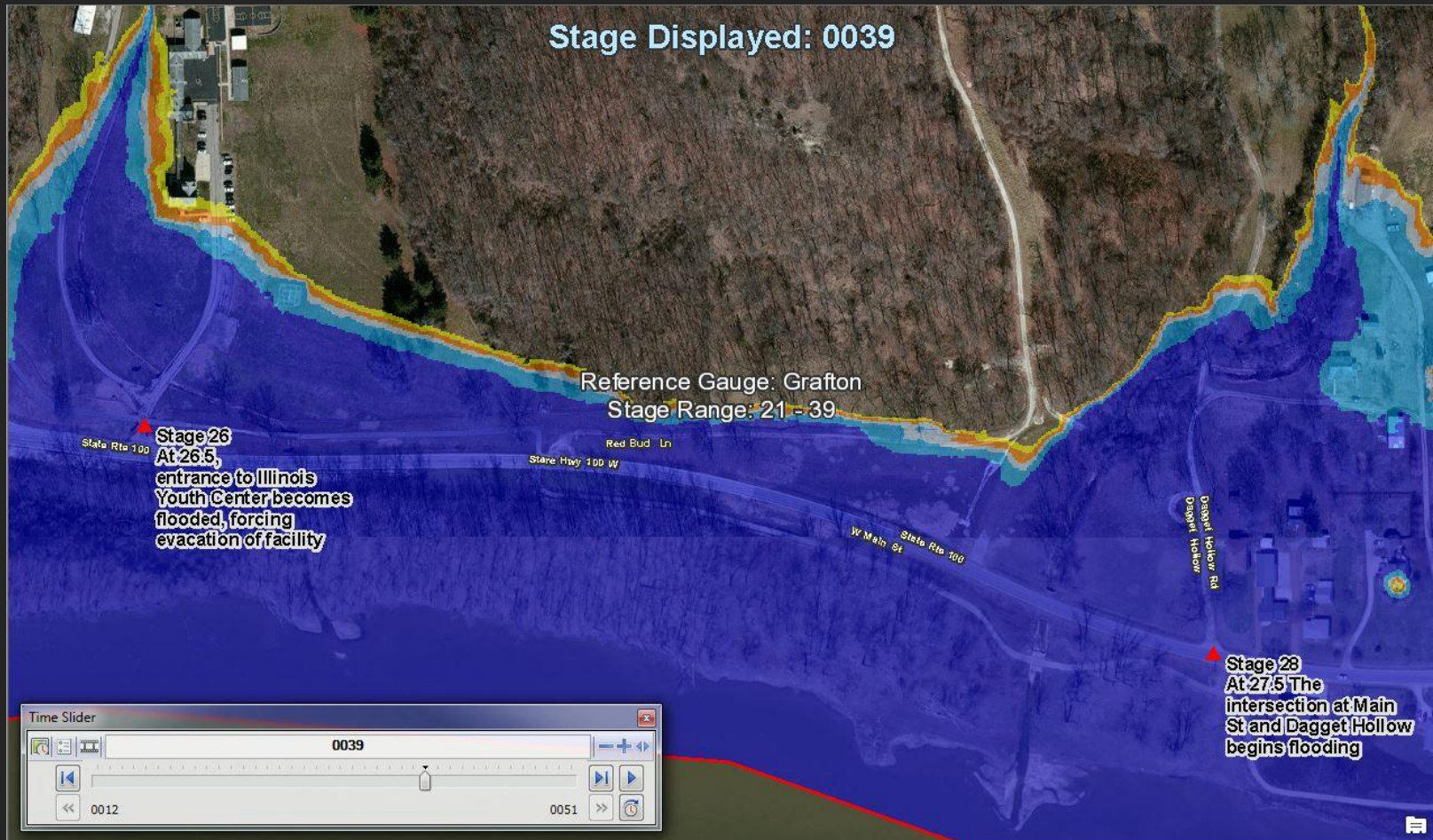
3 Miles West Of Gauge





# Grafton

3 Miles West Of Gauge



# Pontoosuc

Mapping 20 Miles Downstream  
Of River Gauge



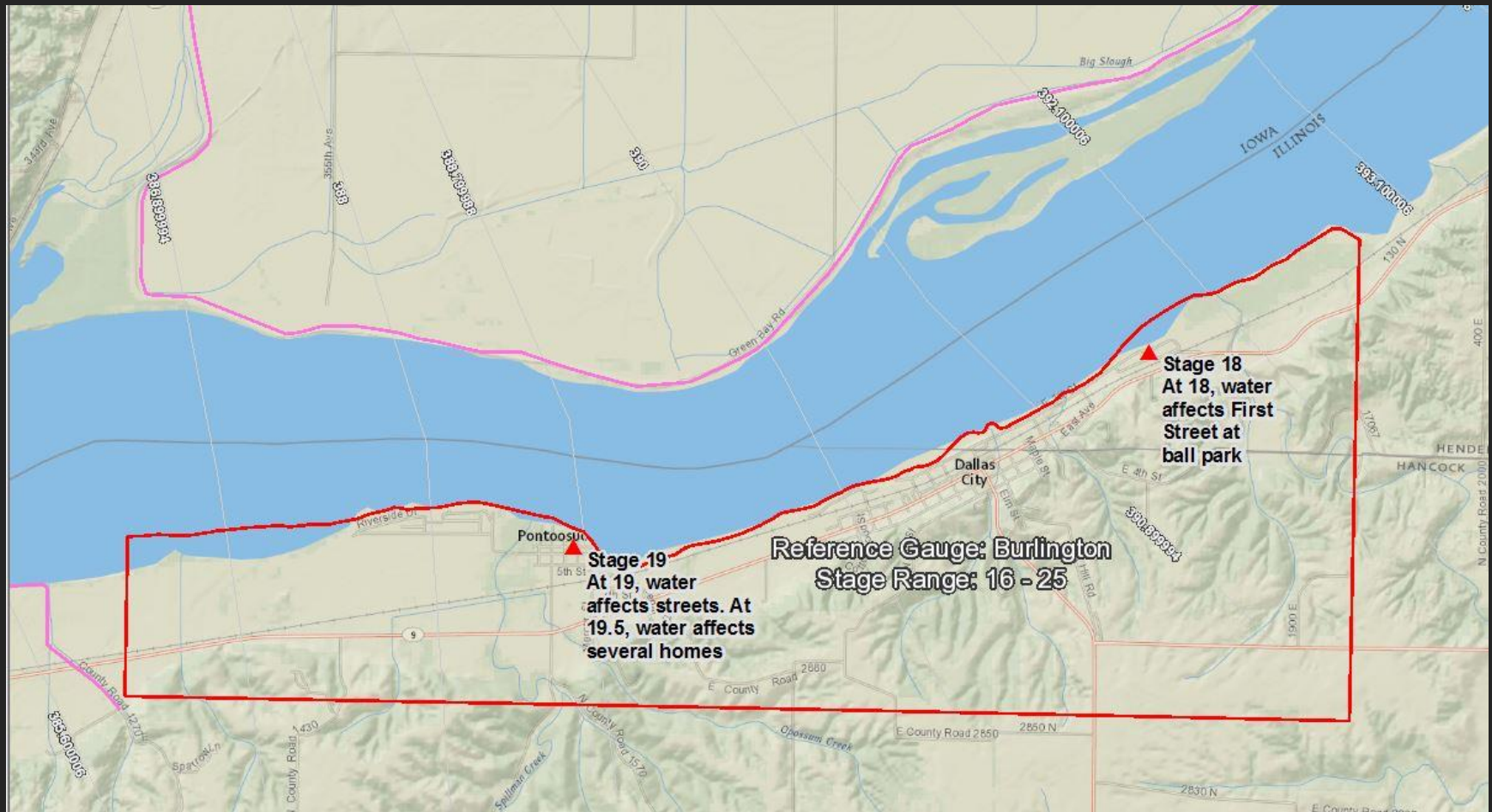
Dallas City



Pontoosuc



# Pontoosuc



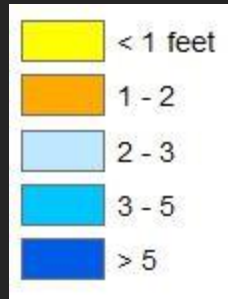


# Pontoosuc

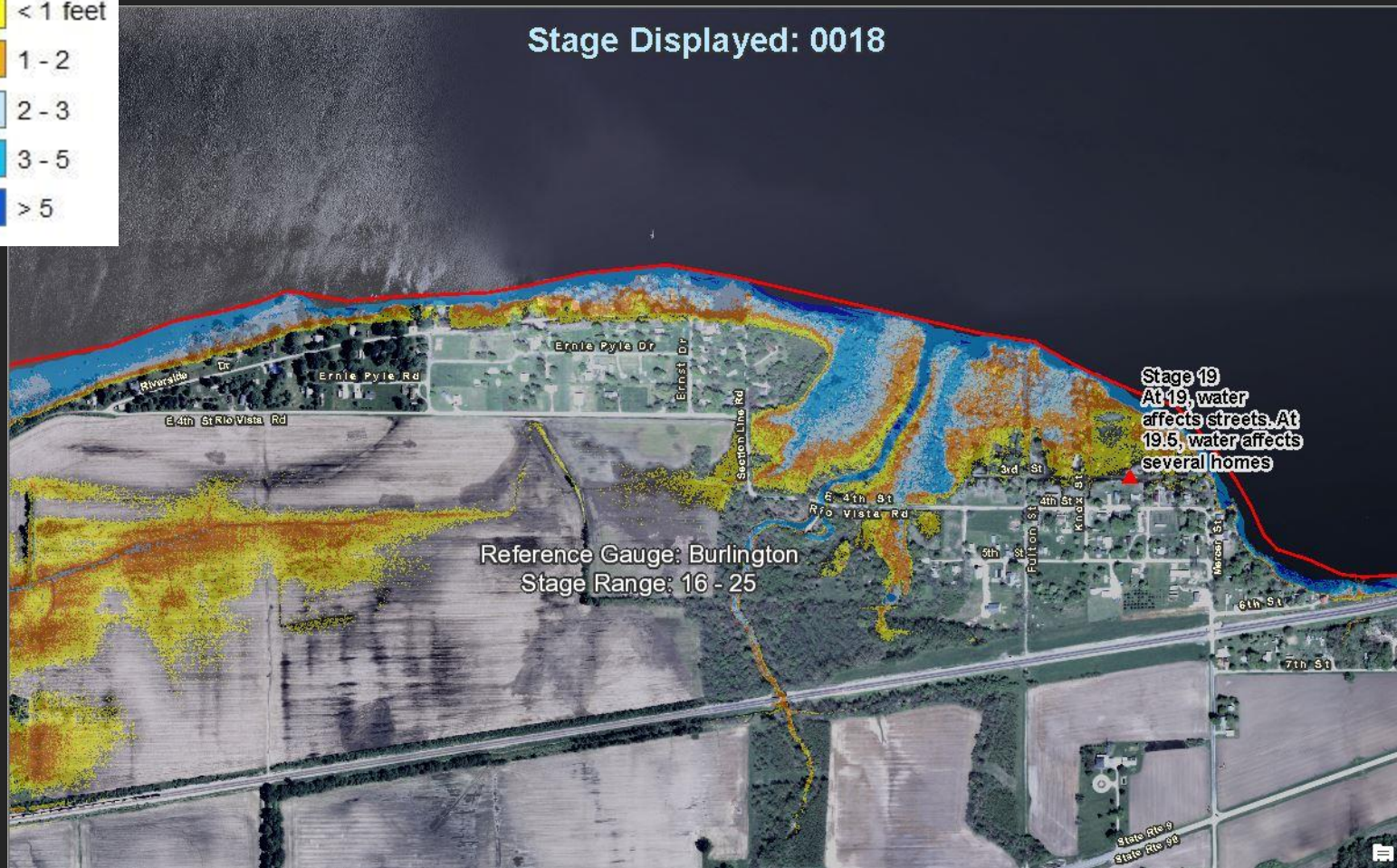




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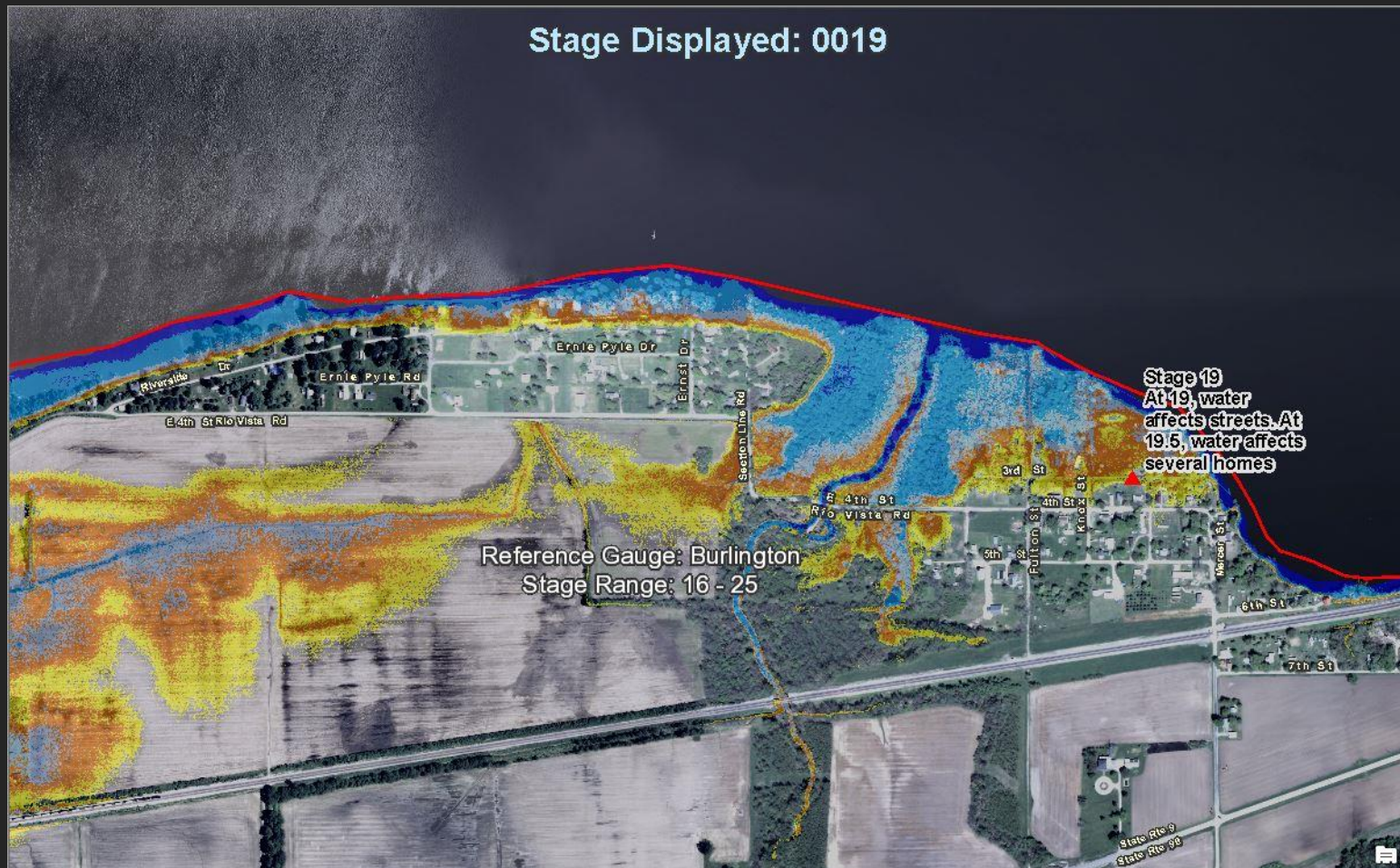


Stage Displayed: 0018



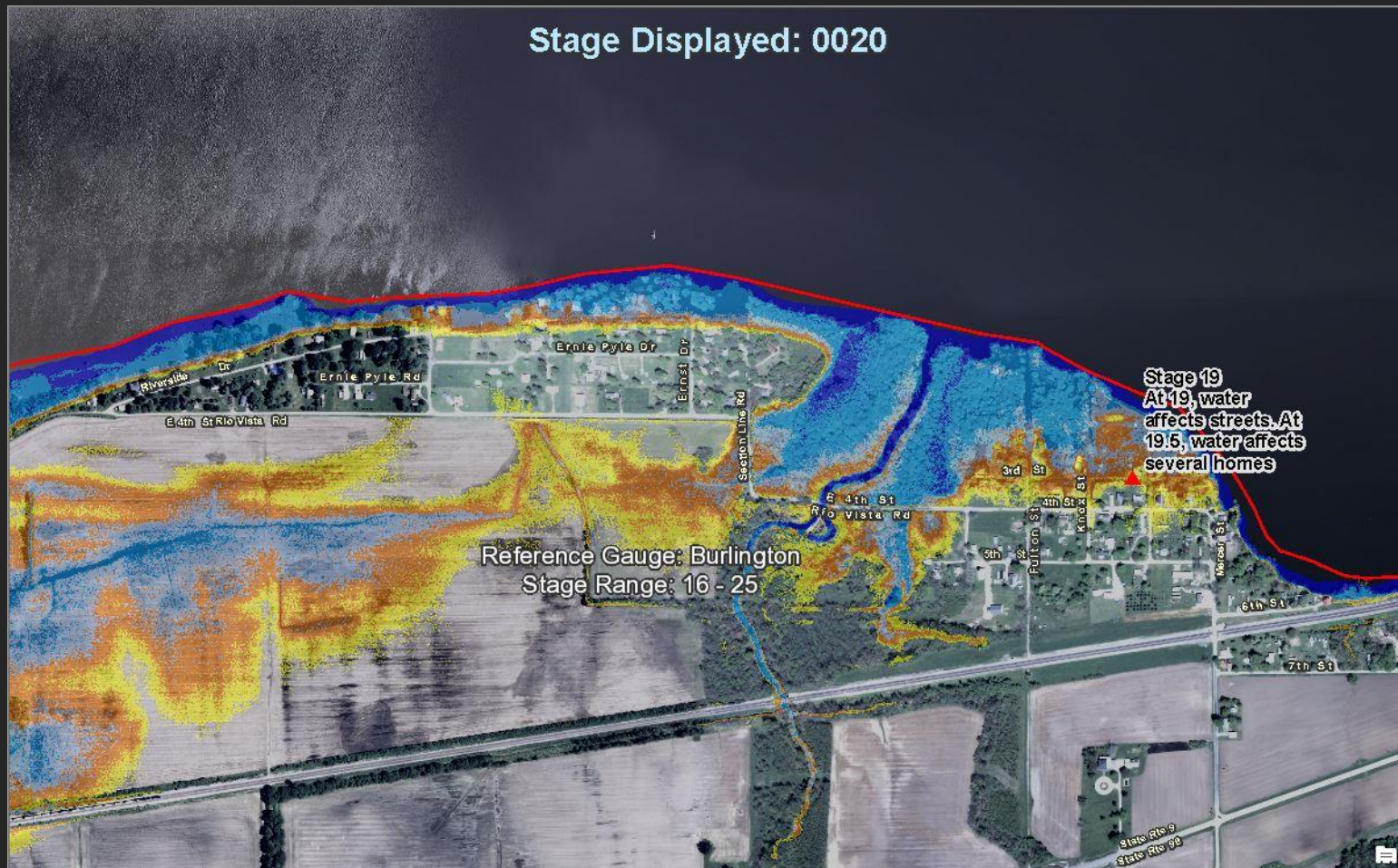


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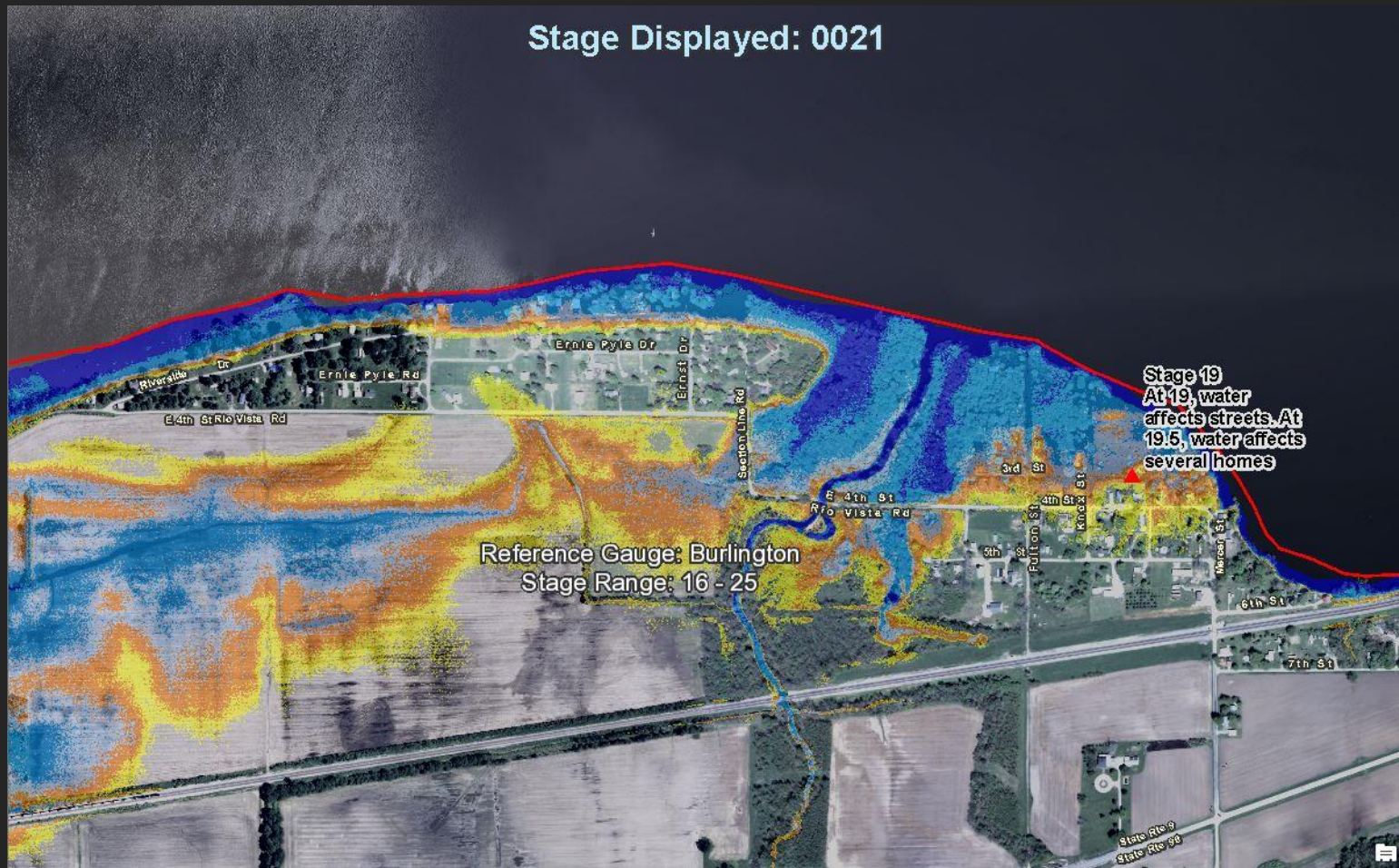


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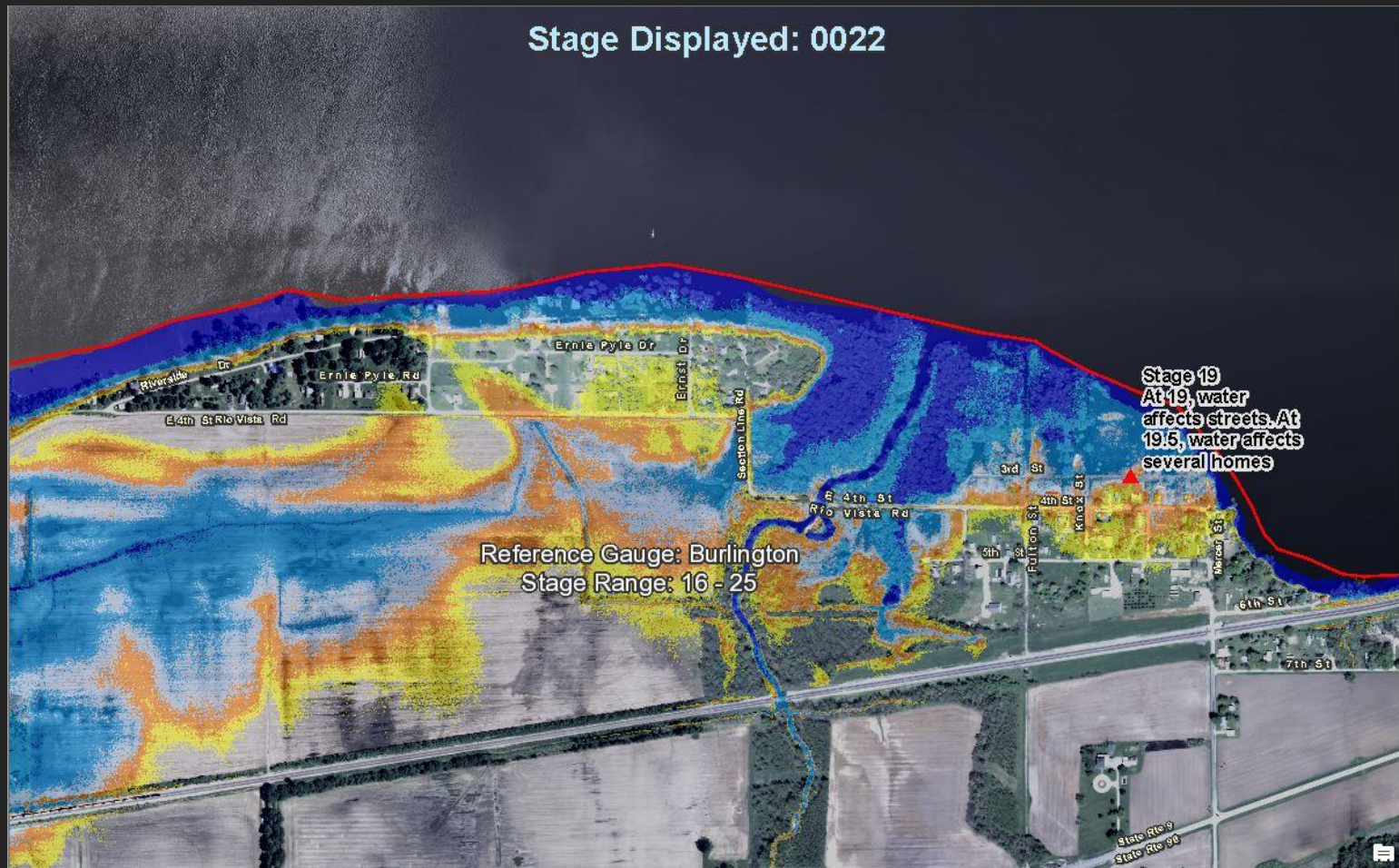


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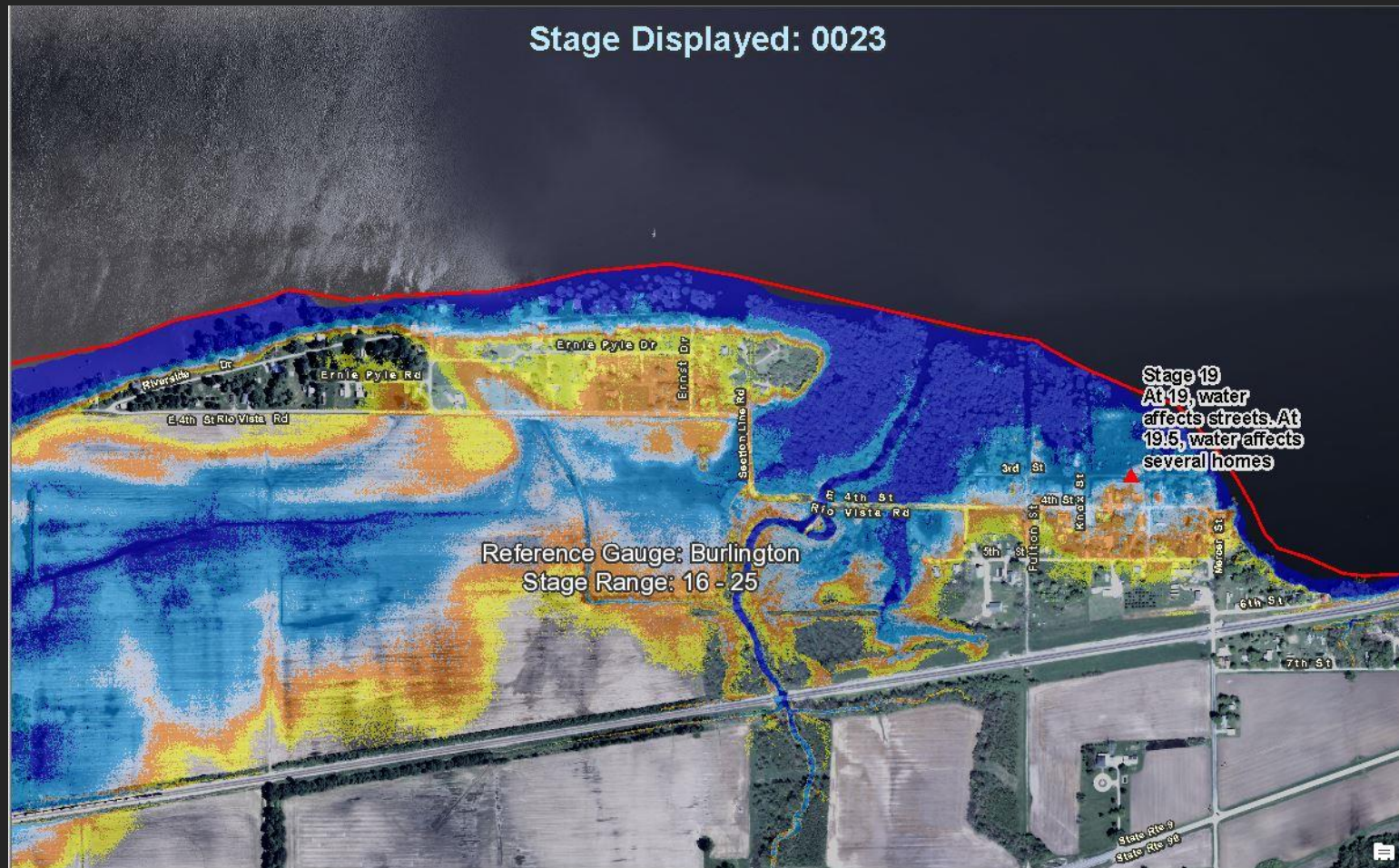


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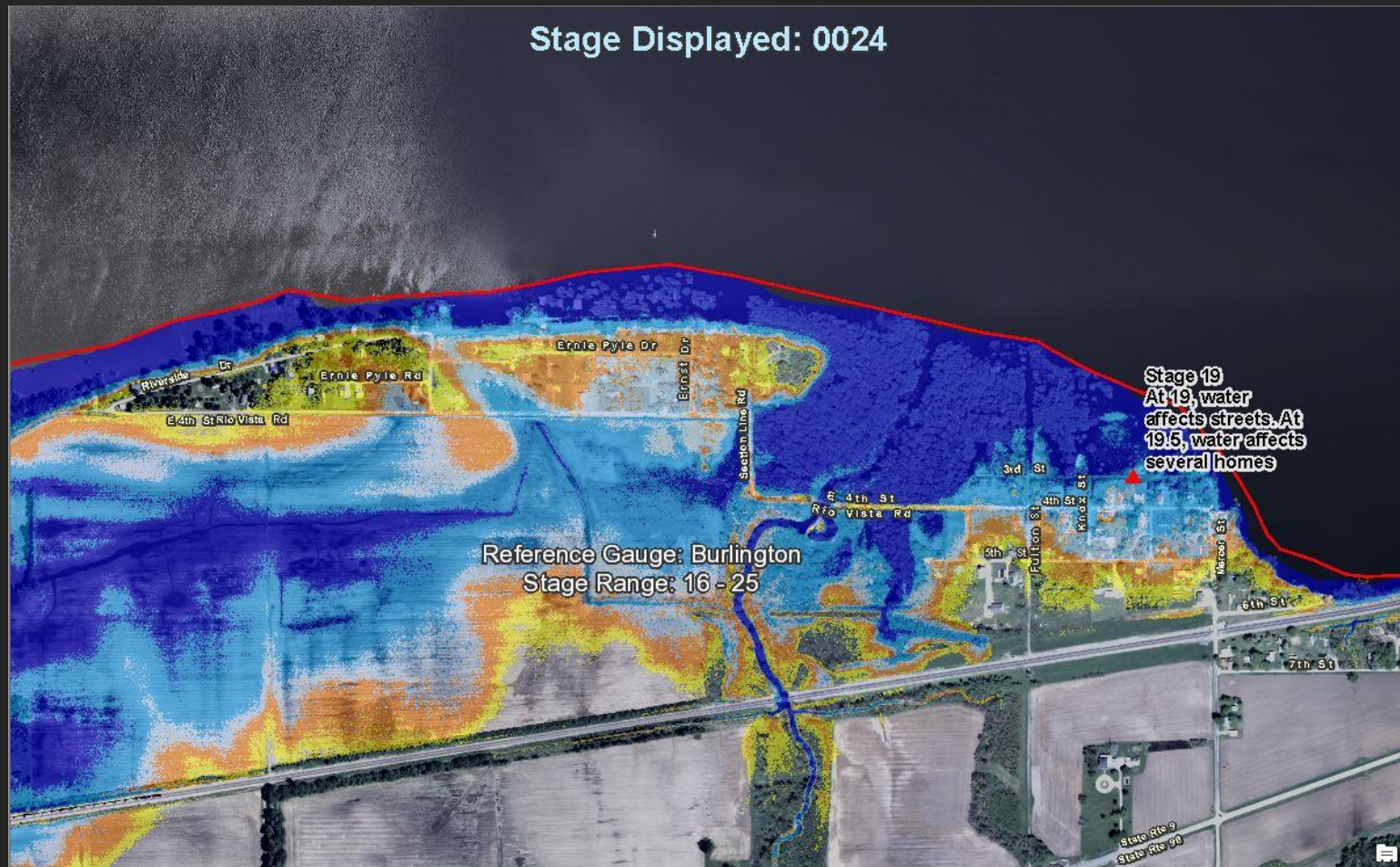


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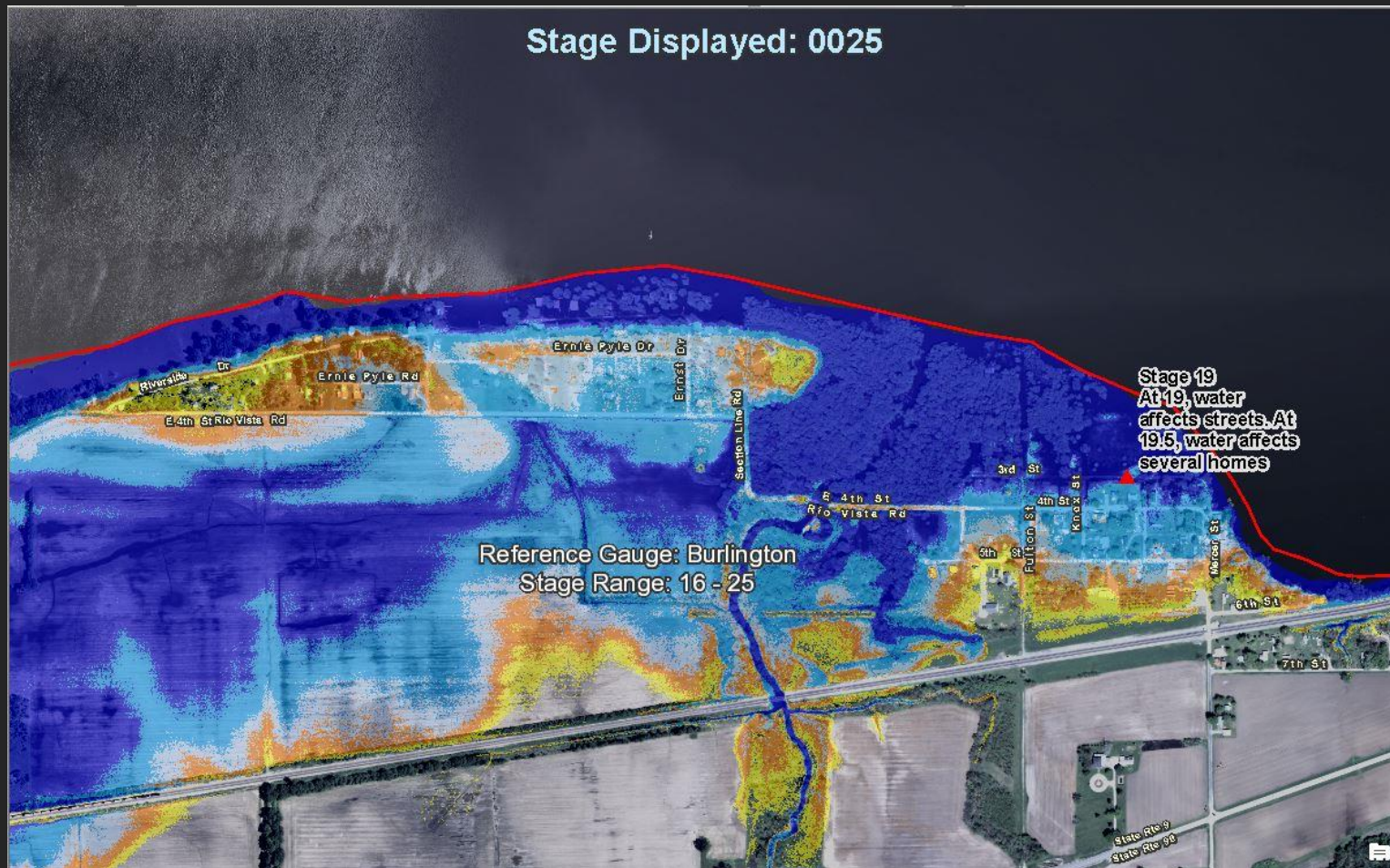


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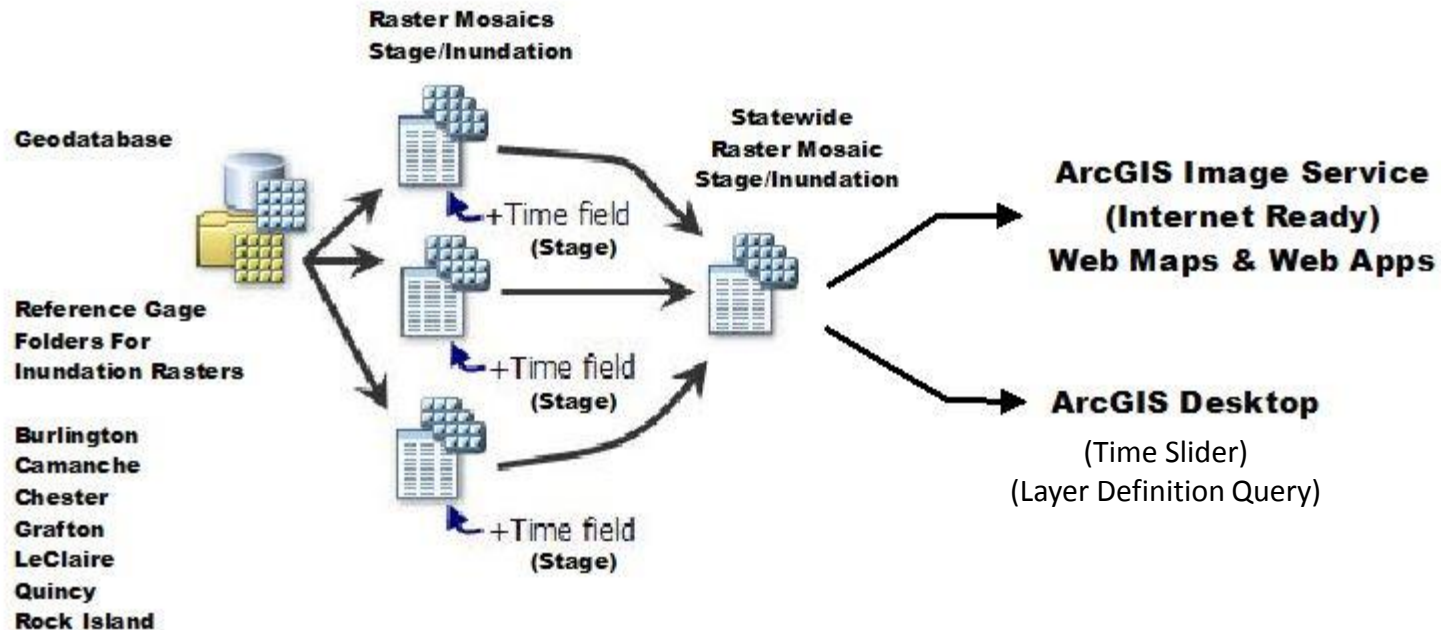




# Pontoosuc



# Storage & Distribution



- 100 stage/inundation raster files
- Depth Category Raster 1/10 file size of depth raster



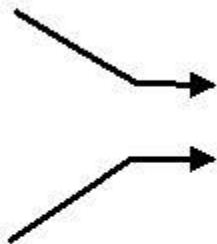
# Distribution

**ArcGIS Image Service  
(Internet Ready)**

**Inundation Raster Library**

**ArcGIS Map Service  
(Internet Ready)**

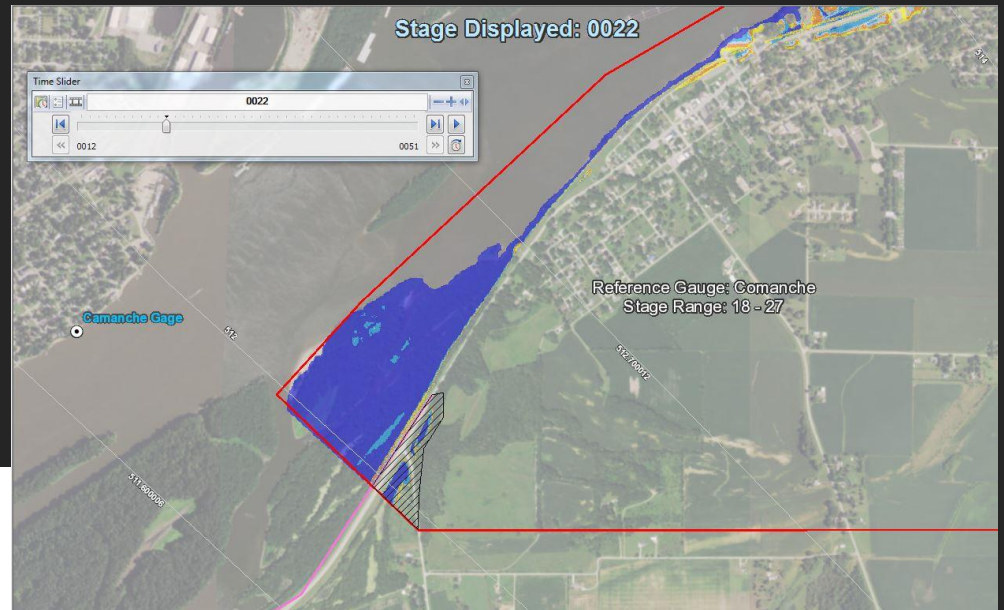
**Stream Gauges  
UNET Model Cross Sections  
Extent of Inundation Mapping  
Levee  
Levee Reduced Risk Area**



(Time Slider)

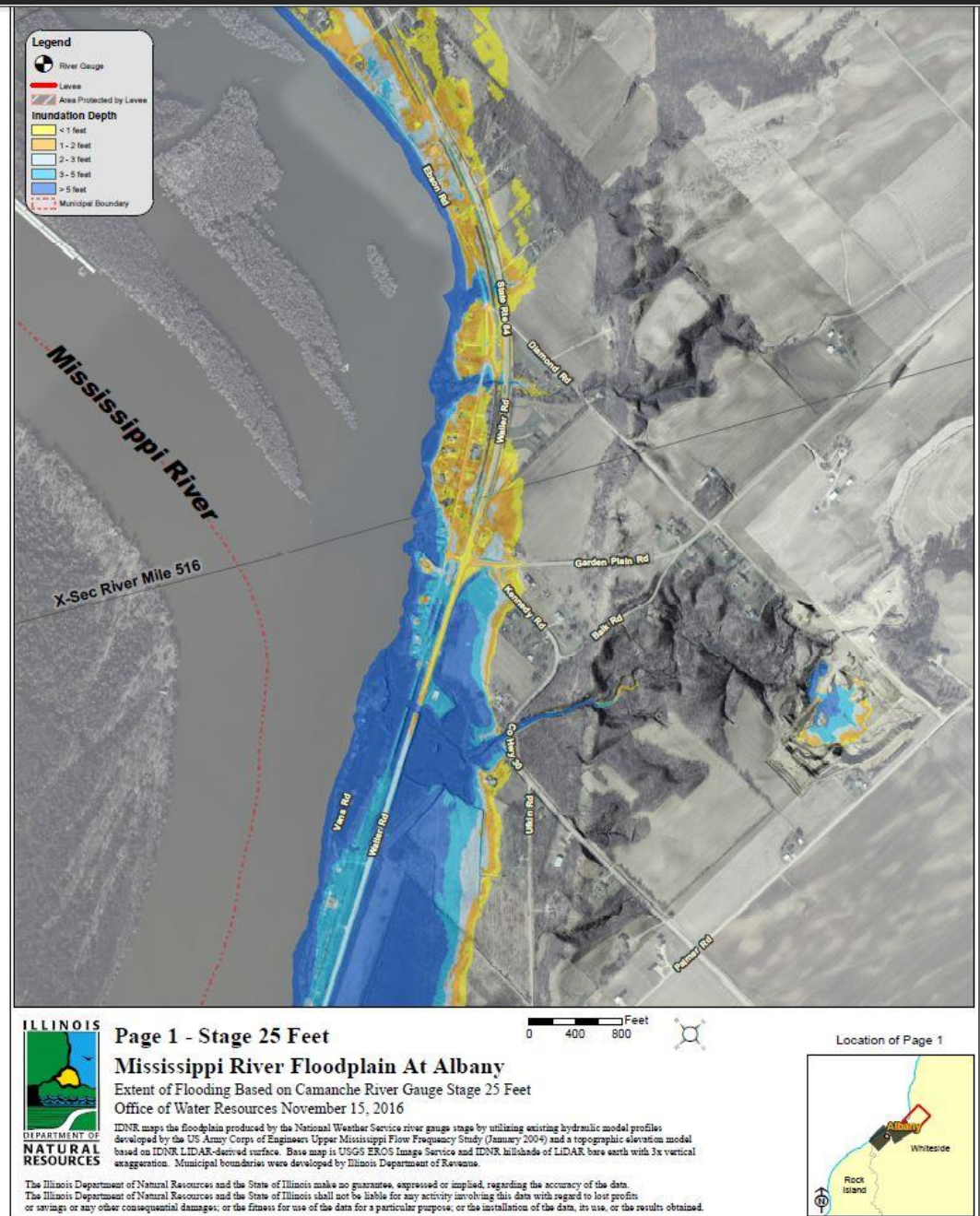
**ArcGIS Desktop  
Or  
ArcGIS Web Map or App**

Currently Requires Customization of  
Time Slider Widget



# Distribution

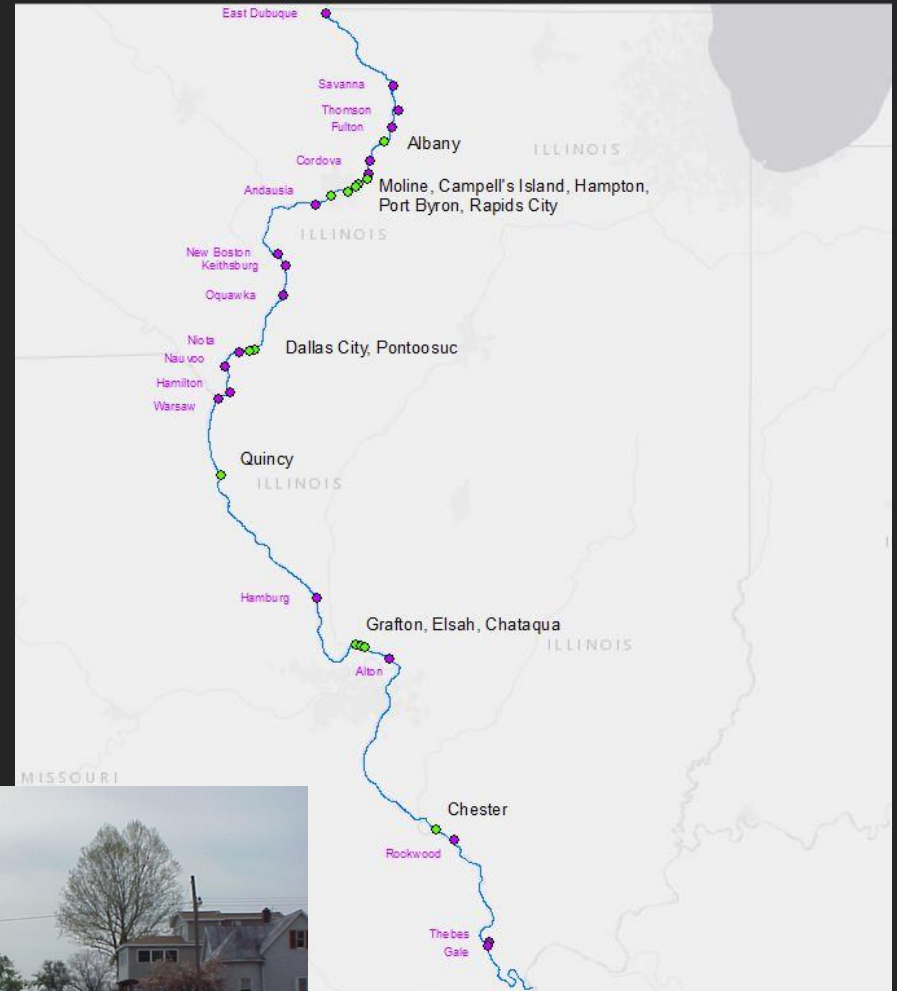
- PDF Map Book
- Multiple Pages Per Stage
- Scaled
- Times When Computer Not Available





# Future

- ArcGIS Services to IEMA
- Map remaining communities
- Customize Web App Time Slider Widget for Web Mapping App
- LiDAR building footprints and additional building information?
- Evaluate applying static mapping methodology for other rivers?
- NOAA National Water Model forecast data for dynamic mapping?



# Questions?

