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.

D.A. = 713,397 sq.mi.

D.A. = 81,600 sq.mi.
Mississippi River Flooding

June 2008

April – May 2011
Mississippi River Flooding

July 2014

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 Gauges

- 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

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Reference Elevation (NGVD29)</th>
<th>Flood Stage</th>
<th>Moderate Stage</th>
<th>Major Flood Stage</th>
<th>Historic Crest</th>
<th>Inundation Mapping: vertical adjustment of water surface to datum of LIDAR topo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafton</td>
<td>403.79</td>
<td>421.79 (18ft)</td>
<td>427.79 (24ft)</td>
<td>432.79 (29ft)</td>
<td>38.2ft</td>
<td>08/01/1993</td>
</tr>
</tbody>
</table>

**At Grafton Gauge (RM 218.02)**

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

<table>
<thead>
<tr>
<th>Stage 19' Elev</th>
<th>Stage 20' Elev</th>
<th>Stage 21' Elev</th>
<th>Stage 22' Elev</th>
<th>Stage 23' Elev</th>
<th>Stage 24' Elev</th>
<th>Stage 25' Elev</th>
<th>Stage 26' Elev</th>
<th>Stage 27' Elev</th>
<th>Stage 28' Elev</th>
<th>Stage 29' Elev</th>
<th>Stage 30' Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>422.8' Event</td>
<td>423.8' Event</td>
<td>424.8' Event</td>
<td>425.8' Event</td>
<td>426.8' Event</td>
<td>427.8' Event</td>
<td>428.8' Event</td>
<td>429.8' Event</td>
<td>430.8' Event</td>
<td>431.8' Event</td>
<td>432.8' Event</td>
<td>433.8' Event</td>
</tr>
<tr>
<td>2.3 Yr</td>
<td>2.9 Yr</td>
<td>3.5 Yr</td>
<td>4.1 Yr</td>
<td>4.6 Yr</td>
<td>4.8 Yr</td>
<td>5.0 Yr</td>
<td>5.2 Yr</td>
<td>5.4 Yr</td>
<td>5.6 Yr</td>
<td>5.8 Yr</td>
<td>6.0 Yr</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>X-Sect River Mile</th>
<th>Stage 21 Elevation (feet)</th>
<th>Stage 22 Elevation (feet)</th>
<th>Stage 23 Elevation (feet)</th>
<th>Stage 24 Elevation (feet)</th>
<th>Stage 25 Elevation (feet)</th>
<th>Stage 26 Elevation (feet)</th>
<th>Stage 27 Elevation (feet)</th>
<th>Stage 28 Elevation (feet)</th>
<th>Stage 29 Elevation (feet)</th>
<th>Stage 30 Elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>212.38</td>
<td>423.4</td>
<td>426.4</td>
<td>429.4</td>
<td>432.4</td>
<td>427.2</td>
<td>428.3</td>
<td>429.5</td>
<td>430.6</td>
<td>431.7</td>
<td>432.8</td>
</tr>
<tr>
<td>213.87</td>
<td>425.8</td>
<td>426.8</td>
<td>429.8</td>
<td>432.8</td>
<td>427.6</td>
<td>428.6</td>
<td>429.8</td>
<td>430.9</td>
<td>432.0</td>
<td>433.1</td>
</tr>
<tr>
<td>215.09</td>
<td>424.0</td>
<td>425.1</td>
<td>426.1</td>
<td>427.0</td>
<td>428.0</td>
<td>429.0</td>
<td>430.7</td>
<td>432.2</td>
<td>433.3</td>
<td>433.3</td>
</tr>
<tr>
<td>216.55</td>
<td>424.4</td>
<td>425.5</td>
<td>426.5</td>
<td>427.4</td>
<td>428.4</td>
<td>429.4</td>
<td>430.5</td>
<td>431.5</td>
<td>432.5</td>
<td>433.5</td>
</tr>
<tr>
<td>R218.02</td>
<td>424.8</td>
<td>425.8</td>
<td>426.8</td>
<td>427.8</td>
<td>428.8</td>
<td>429.8</td>
<td>430.8</td>
<td>431.8</td>
<td>432.8</td>
<td>433.8</td>
</tr>
<tr>
<td>218.86</td>
<td>425.1</td>
<td>426.2</td>
<td>427.2</td>
<td>428.1</td>
<td>429.1</td>
<td>430.1</td>
<td>431.1</td>
<td>432.1</td>
<td>433.1</td>
<td>434.1</td>
</tr>
<tr>
<td>220.02</td>
<td>425.7</td>
<td>426.7</td>
<td>427.8</td>
<td>428.6</td>
<td>429.6</td>
<td>430.6</td>
<td>431.5</td>
<td>432.5</td>
<td>433.5</td>
<td>434.5</td>
</tr>
<tr>
<td>221.05</td>
<td>426.3</td>
<td>427.3</td>
<td>428.3</td>
<td>429.1</td>
<td>430.0</td>
<td>431.0</td>
<td>431.9</td>
<td>432.9</td>
<td>433.8</td>
<td>434.8</td>
</tr>
</tbody>
</table>
Gauge Elevation to Frequency
Frequency to Elevation at Model Cross Sections

Albany Cross Sections

ELEVATION

FREQUENCY

Camanche
River Mile 512.7
River Mile 514
River Mile 515
River Mile 516
River Mile 517
What is LiDAR?

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.
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.
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 inundates.

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 pump house 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 Mentro.

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 446 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

Mapping extends five miles
Grafton

Close Proximity To Gauge

Stage Displayed: 0024

- < 1 feet
- 1 - 2
- 2 - 3
- 3 - 5
- > 5

Stage 25
At 24.7 Catholic Church parking lot begins flooding. This represents the lowest point on Main St.

Stage 26
At 25.2 The intersection at Main St & Canal begins flooding.

Stage 27
At 24.5 Stage, City of Grafton begins detour of traffic along Rte 100 at Evans St.
Grafton

Close Proximity To Gauge

Stage Displayed: 0025

Stage 25:
At 25.2 The intersection at Main St & Canal begins flooding.

Stage 25:
At 24.7 Stage, City of Grafton begins detour of traffic along Rt. 100 at Evans St.

Stage 25:
At 24.7 Catholic Church parking lot begins flooding. This represents the lowest point on Main St.
Grafton

Close Proximity To Gauge
Grafton

Close Proximity To Gauge
Grafton

Close Proximity To Gauge
Grafton

Close Proximity To Gauge

Stage Displayed: 0028

Stage 30
At 30.1 water reaches the intersection of Main & Maple St

Stage 26
At 25.8, car wash at Main & Sycamore begins flooding

Stage 26 Intersection closed

Stage 32
At 32.1, Methodist Church at Main St & Vine begins flooding
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

Stage Displayed: 0027

Reference Gauge: Grafton
Stage Range: 21 - 39

Stage 26
At 26.5, entrance to Illinois Youth Center becomes flooded, forcing evacuation of facility

Stage 28
At 27.5, the intersection at Main St and Dagget Hollow begins flooding
Grafton

3 Miles West Of Gauge

Stage Displayed: 0028

Reference Gauge: Grafton
Stage Range: 21 - 39

Stage 28
At 26.5, entrance to Illinois Youth Center becomes flooded, forcing evacuation of facility

Stage 28
At 27.5, the intersection at Main St and Dagget Hollow begins flooding
Grafton

3 Miles West Of Gauge

Stage Displayed: 0039

Reference Gauge: Grafton
Stage Range: 21 - 39

Stage 23
At 27.5, the intersection at Main and Dagget Hollow begins flooding

Stage 23
At 25.5, the entrance to Illinois Youth Center becomes flooded, forcing evacuation of facility
Pontoosuc Mapping 20 Miles Downstream Of River Gauge

Dallas City

Pontoosuc
Pontoosuc

Stage 18
At 18, water affects First Street at ball park

Stage 19
At 19, water affects streets. At 19.5, water affects several homes

Reference Gauge: Burlington
Stage Range: 16 - 25
Pontoosuc
Stage Displayed: 0019

Reference Gauge: Burlington
Stage Range: 16 - 25

Stage 19
At 19, water affects streets. At 19.6, water affects several homes.
Pontoosuc

Stage Displayed: 0021

Reference Gauge: Burlington
Stage Range: 16 - 25

Stage 19
At 19, water affects streets. At 19.5, water affects several homes.
Pontoosuc

Stage Displayed: 0022

Stage 49. At 49, water effects streets. At 19 ft, water affects several homes.

Reference Gauge: Burlington
Stage Range: 16 - 25
Stage Displayed: 0023

Reference Gauge: Burlington
Stage Range: 16 - 25

Stage 19
At 19, water affects streets. At 19.5, water affects several homes.
Pontoosuc

Stage Displayed: 0025

Reference Gauge: Burlington
Stage Range: 16 - 25

Stage 19 at 19' water affects streets. At 18' 5, water affects several homes.
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 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?