New Developments in River Valley Floodplain Mapping Using DEMs:

A Survey of FLDPLN Model Applications

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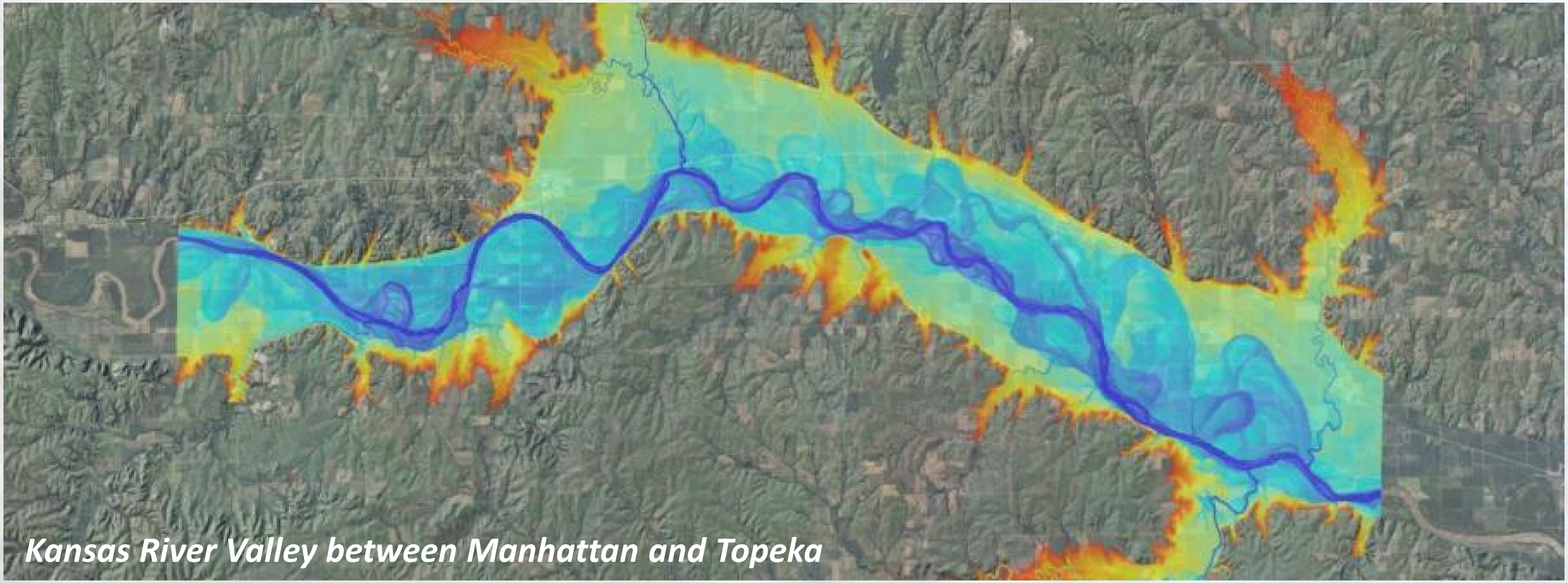
Kansas Biological Survey

ASWM/NFFA Webinar | January 13, 2014

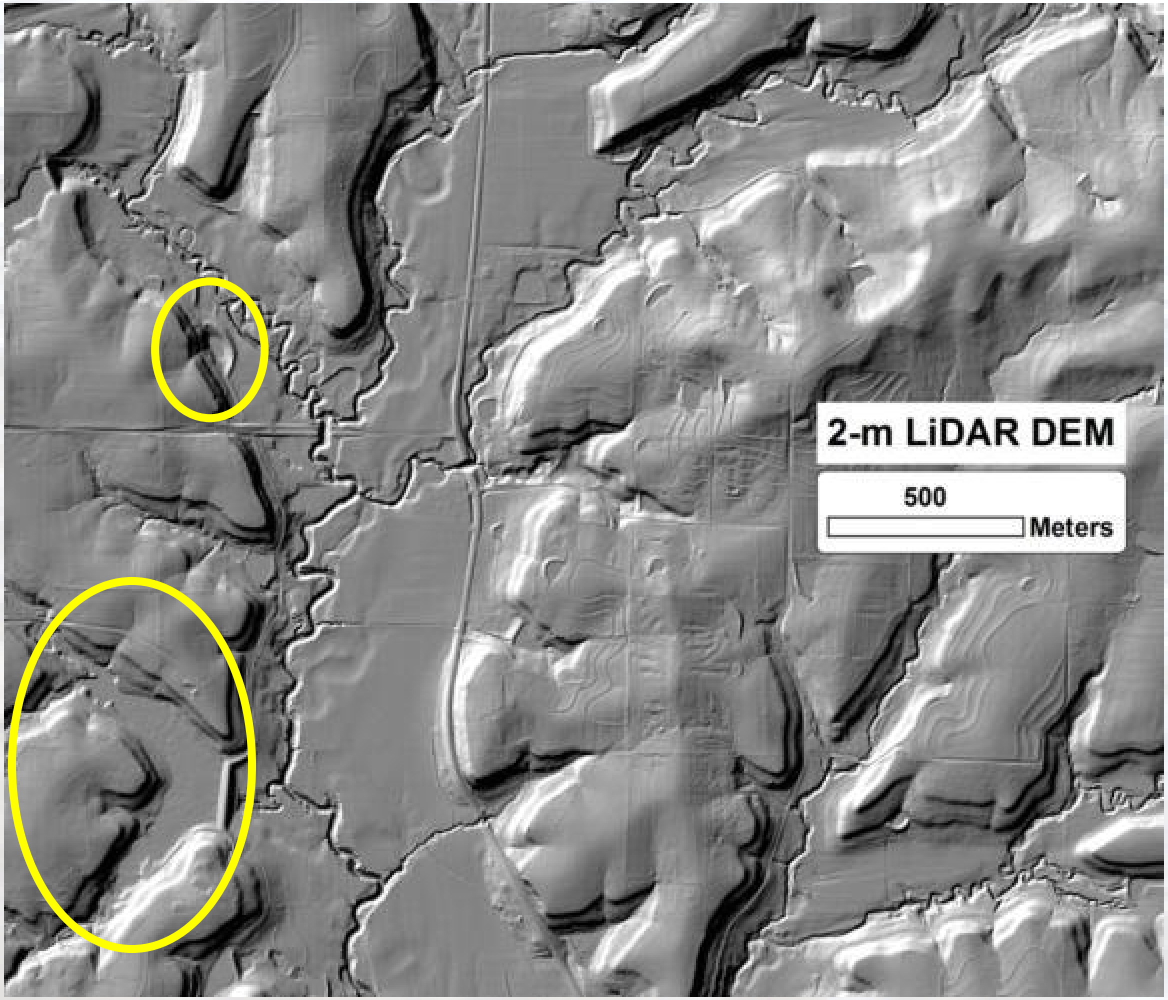
KANSAS BIOLOGICAL SURVEY

KARS
Kansas Applied Remote Sensing



Email: jkastens@ku.edu

Terrain Processing: ***DEM (Digital Elevation Model)***

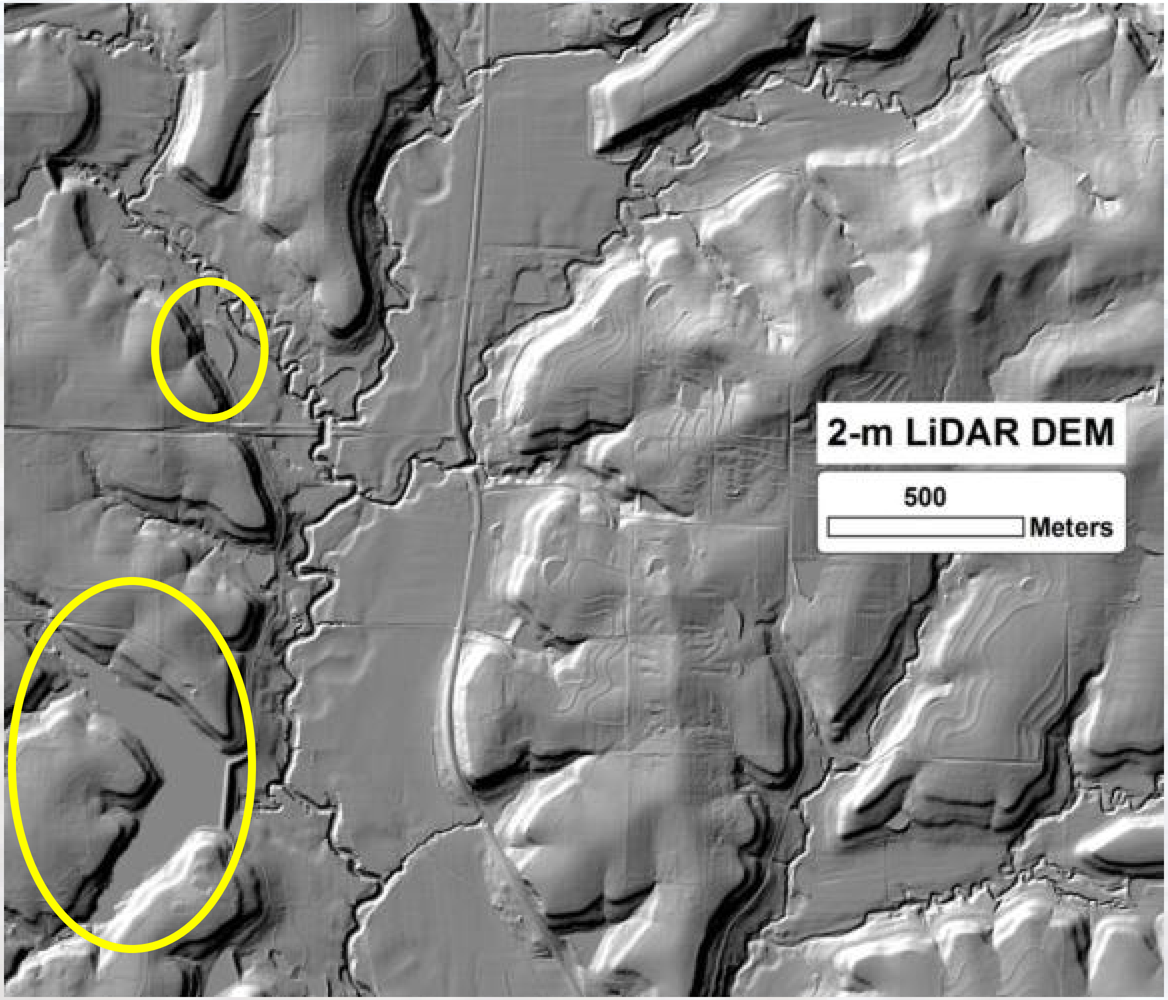


***Unfilled* DEM** (shown in shaded relief)

This DEM was created using LiDAR data.

Shown is a portion of the river valley for **Mud Creek** in **Jefferson County, Kansas.**

Terrain Processing: ***Filled (depressionless) DEM***

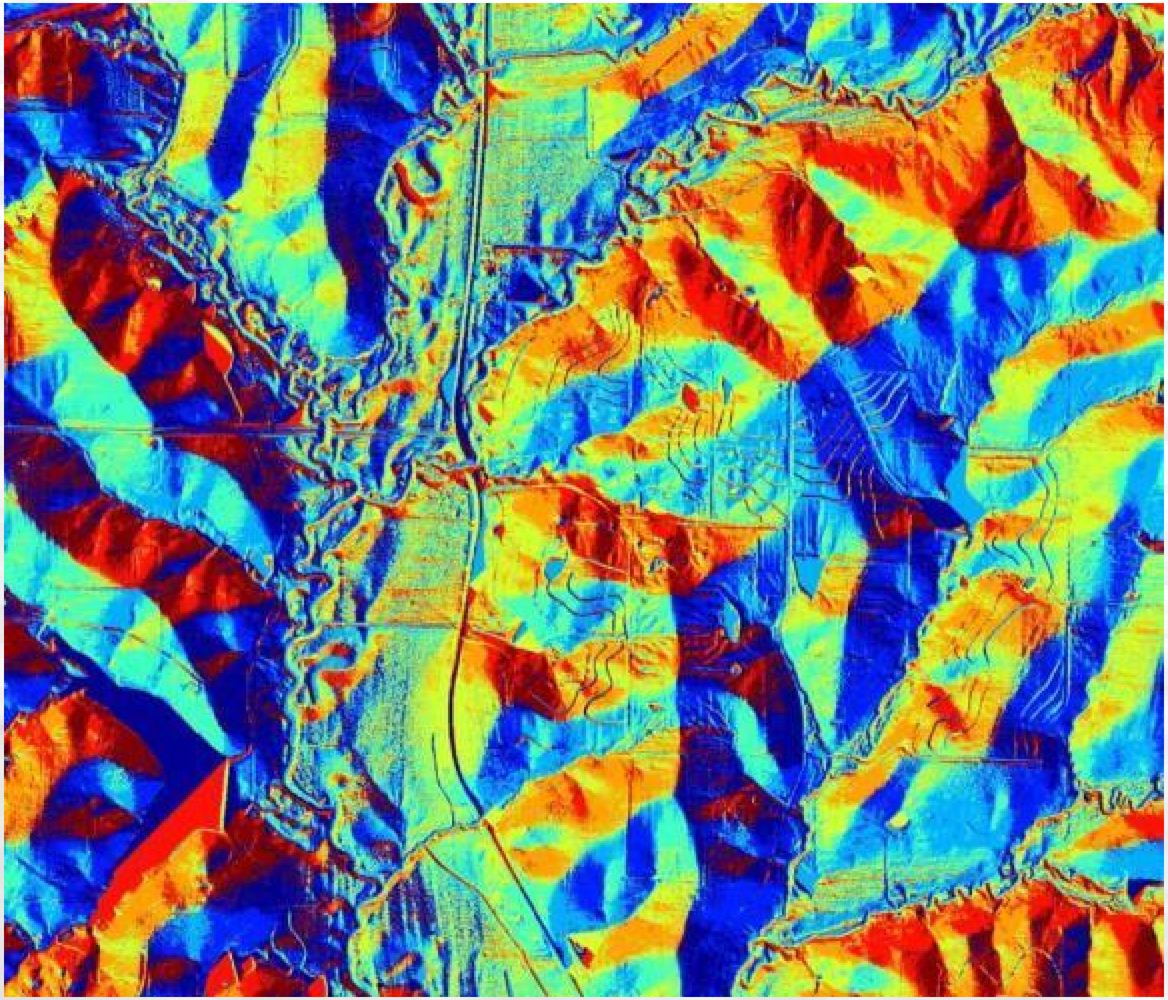


***Filled* DEM** (shown in shaded relief)

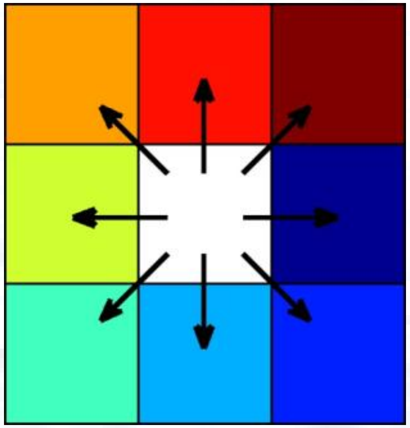
This DEM was created using LiDAR data.

Shown is a portion of the river valley for **Mud Creek** in **Jefferson County, Kansas.**

Terrain Processing: *Flow Direction*



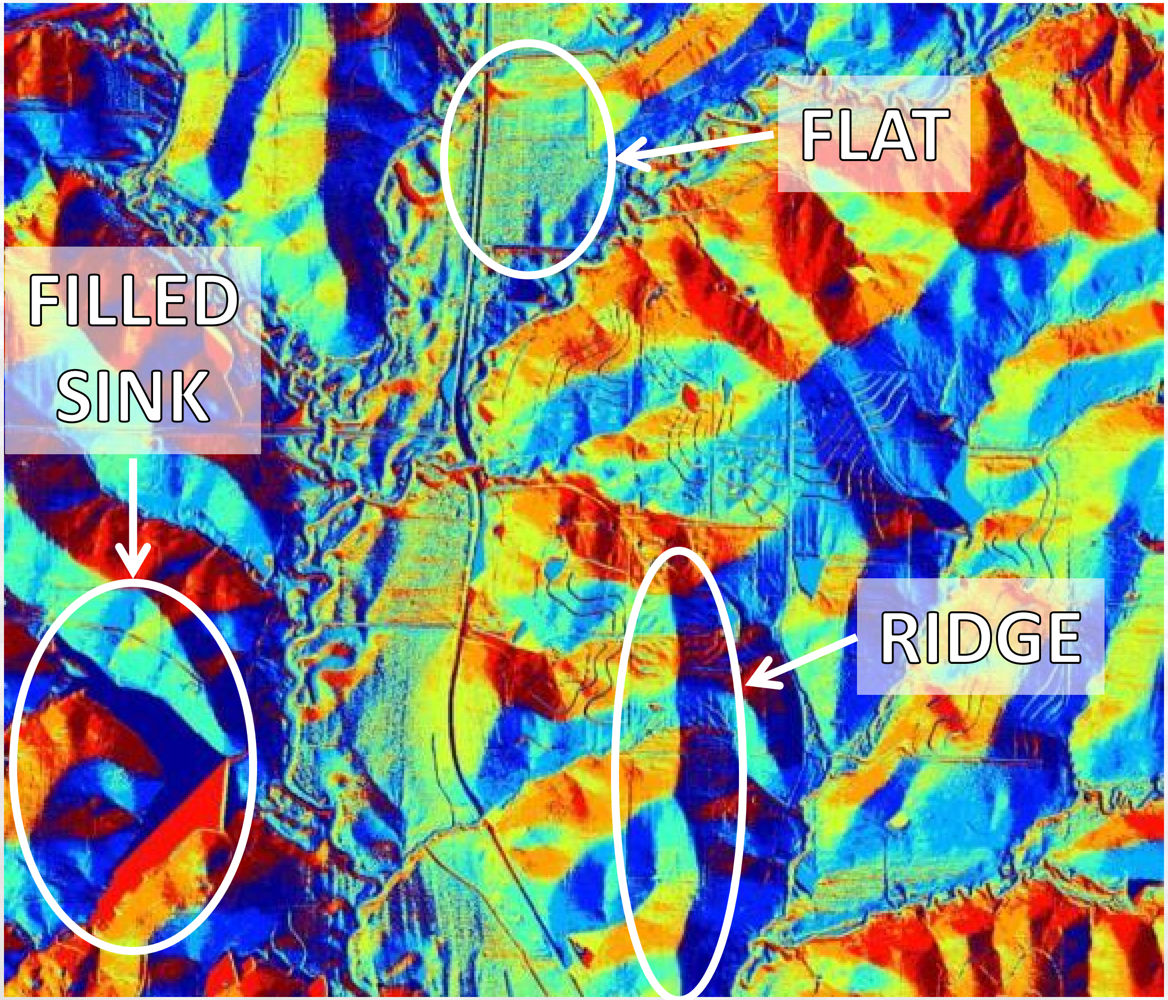
Flow direction map (gradient direction approximation)



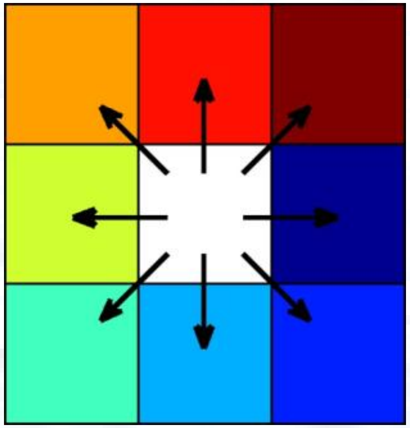
Each pixel is colored based on its **flow direction**.

Navigating by flow direction, every pixel has a single ***exit path*** out of the image.

Terrain Processing: *Flow Direction*



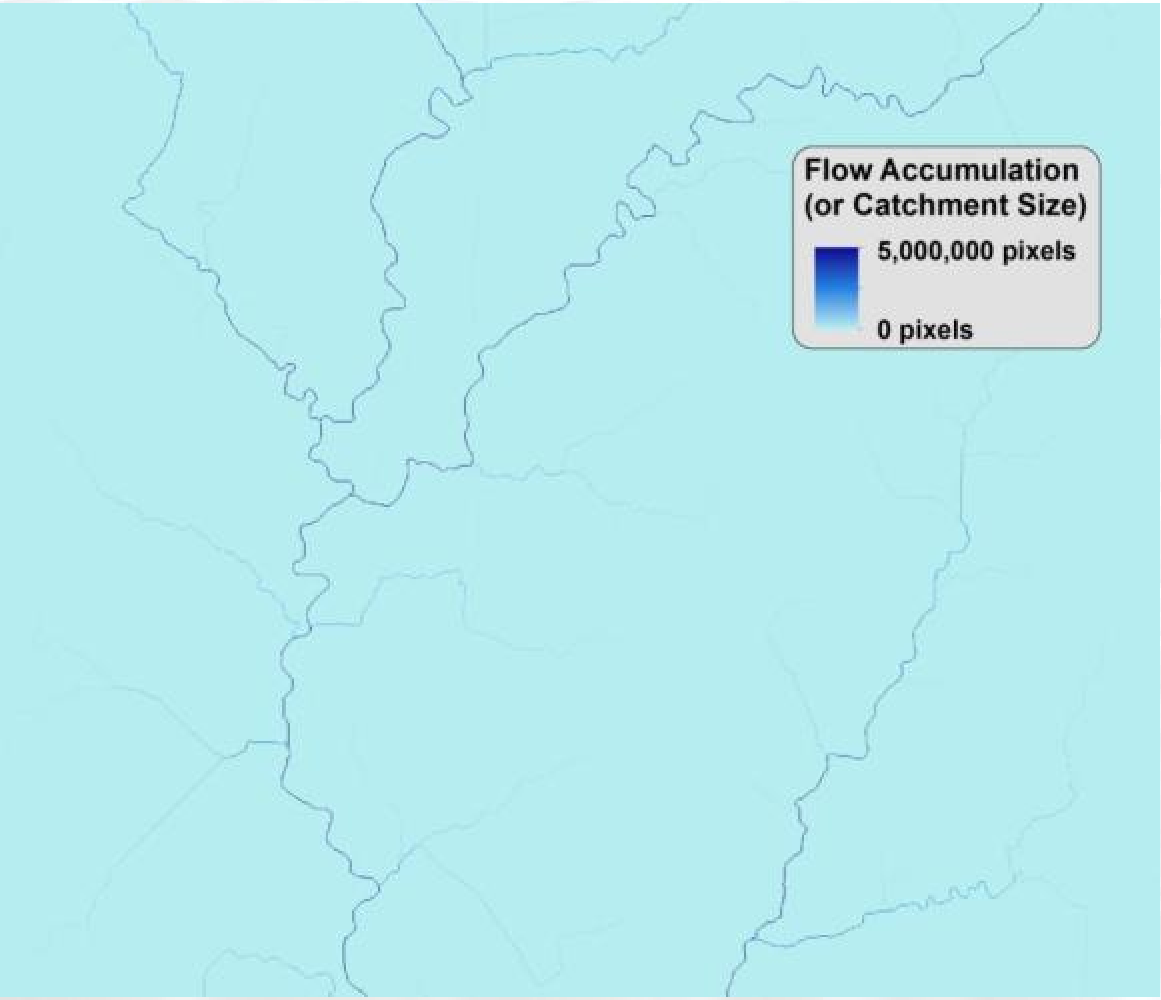
Flow direction map (gradient direction approximation)



Each pixel is colored based on its **flow direction**.

Navigating by flow direction, every pixel has a single ***exit path*** out of the image.

Terrain Processing: *Flow Accumulation*



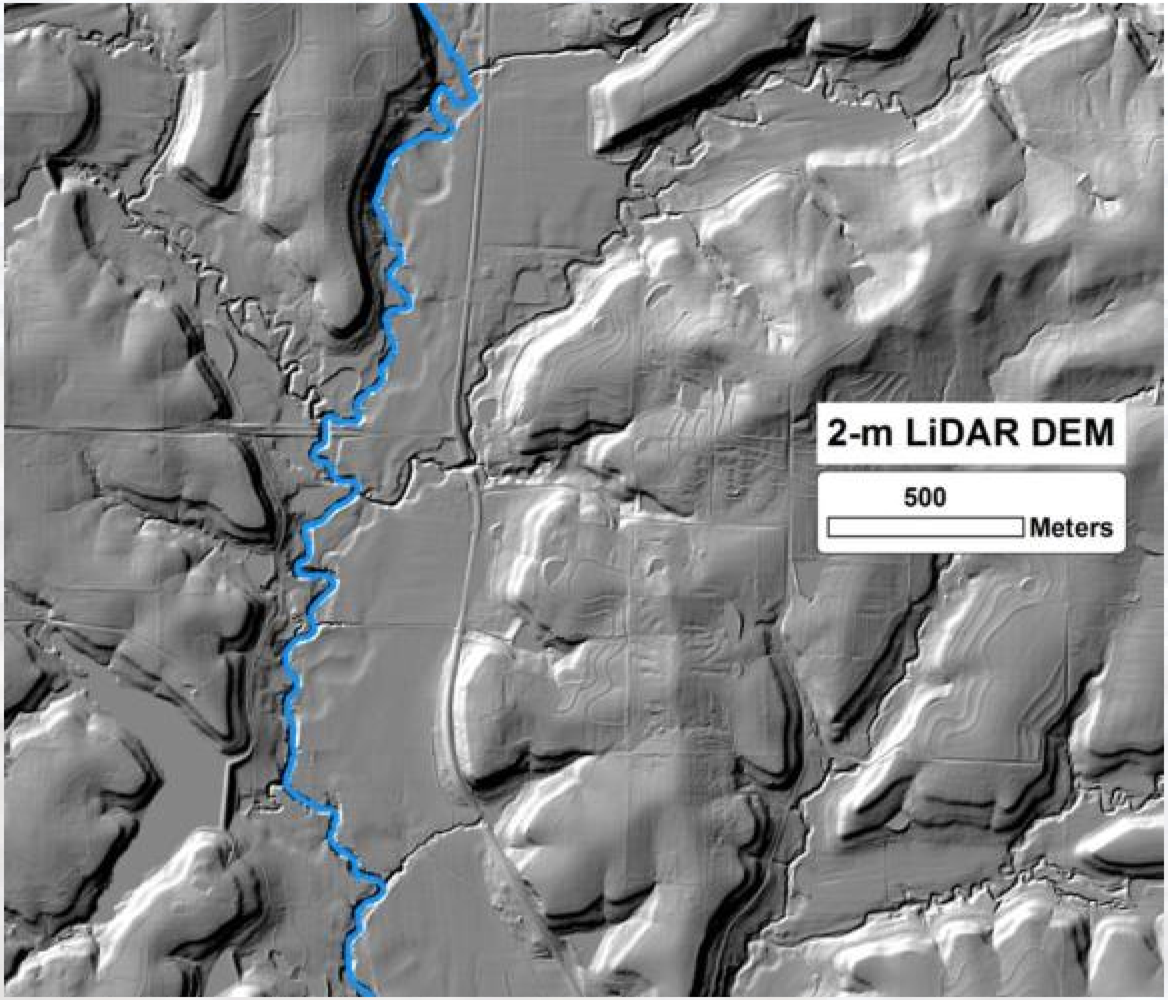
The flow direction map is used to compute **<u>flow accumulation</u>**.

flow accumulation
= catchment size

= the number of exit paths that a pixel belongs to

Flow accumulation map (streamline identification)

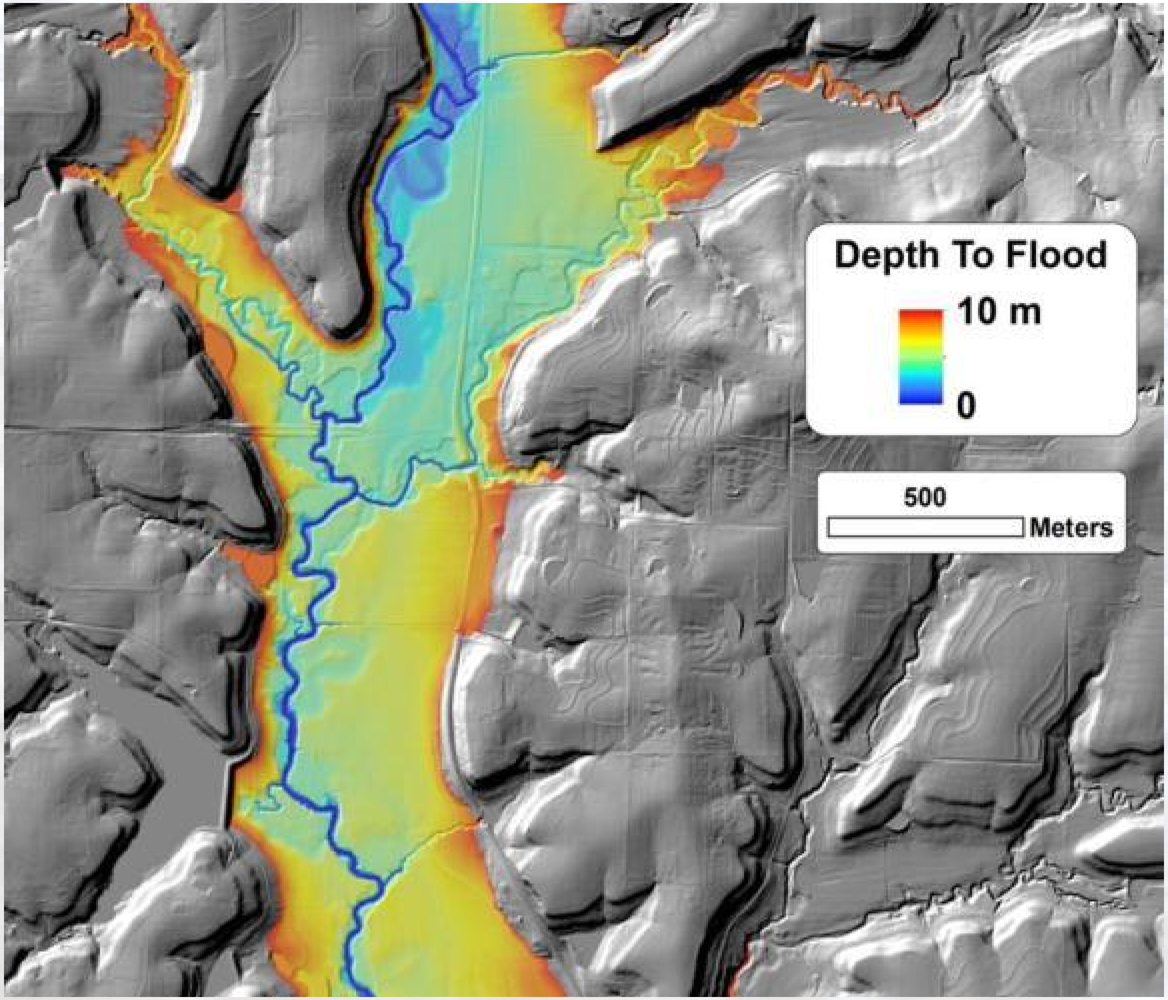
Terrain Processing: ***Stream Delineation***



"Synthetic Stream Network"

Using pixels with a flow accumulation value >10^6 pixels, the **Mud Creek** streamline is identified (shown in blue).

Terrain Processing: *Floodplain Mapping*



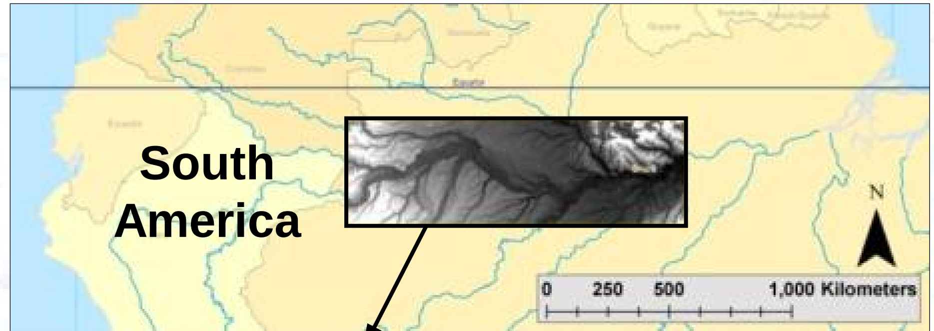
10-m Floodplain (DTF Map)

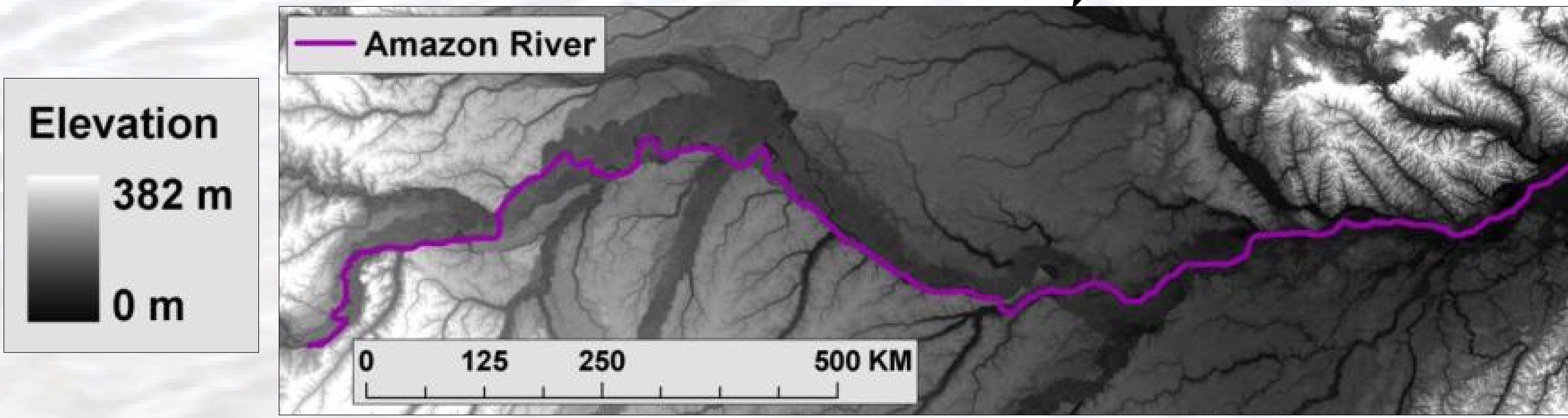
The 10-m floodplain was computed ***for Mud Creek*** using **the FLDPLN model**.

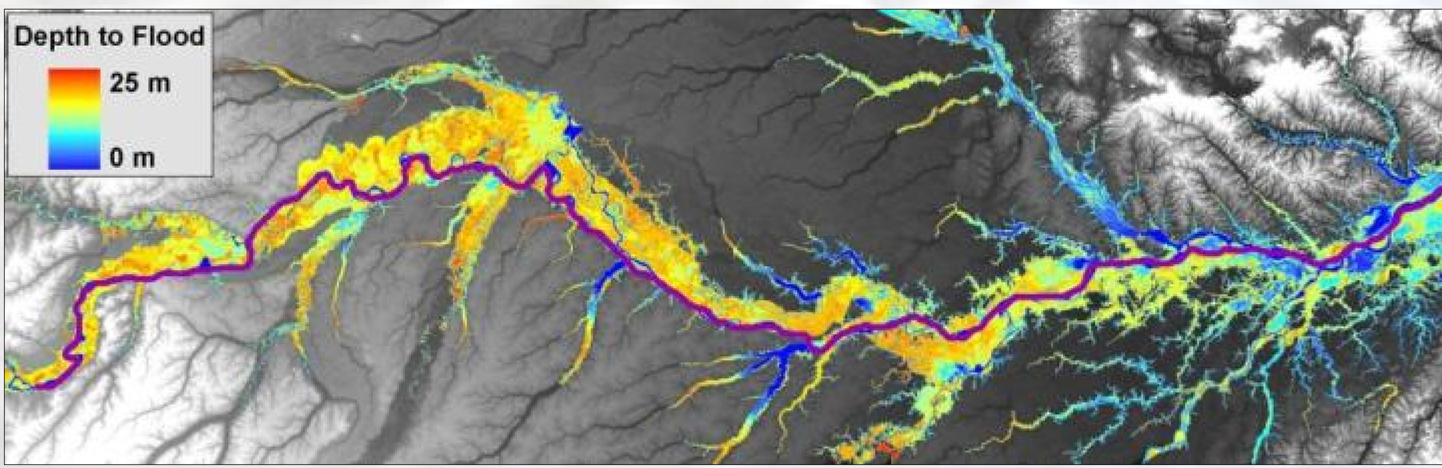
FLDPLN is a static, 2D hydrologic model that requires only DEM data as input.

Using simple surface flow properties, FLDPLN identifies the depth-varying floodplain in reference to the input stream network (floodwater source).

Amazon River in Brazil (1700 km). 90-m SRTM DEM data were used.



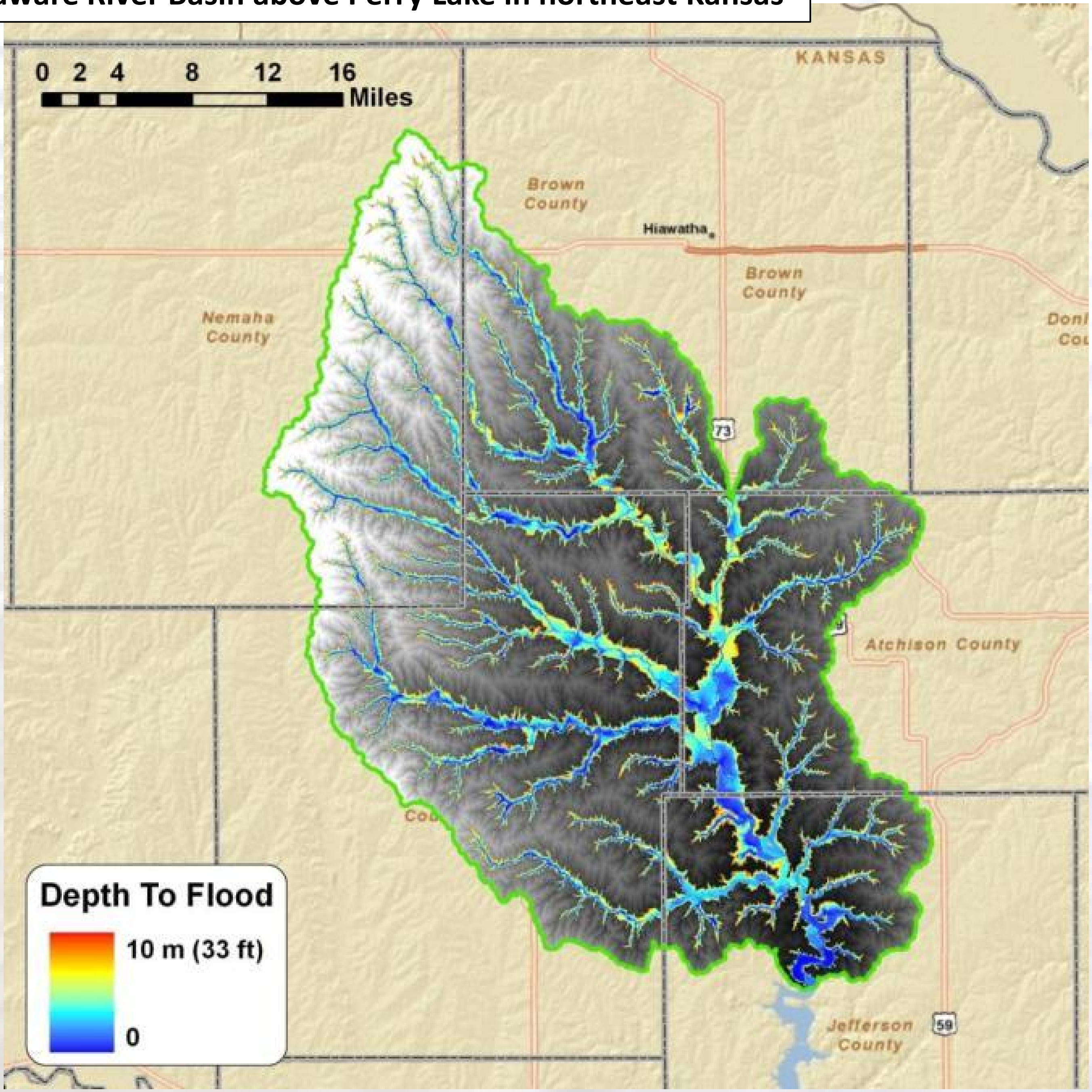




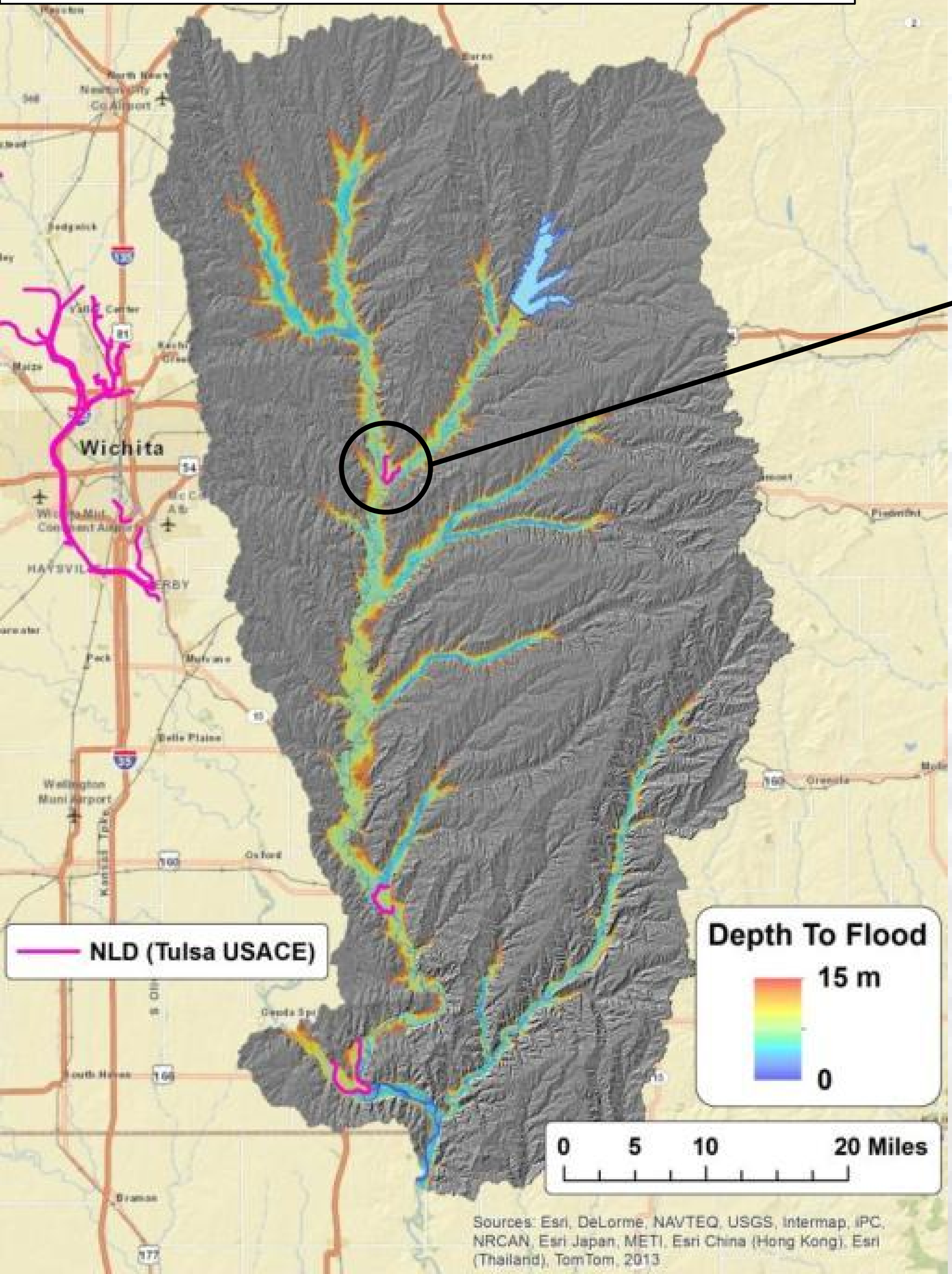
Amazon surface elevation drop in study area: 17 m

1 m per 100 km!

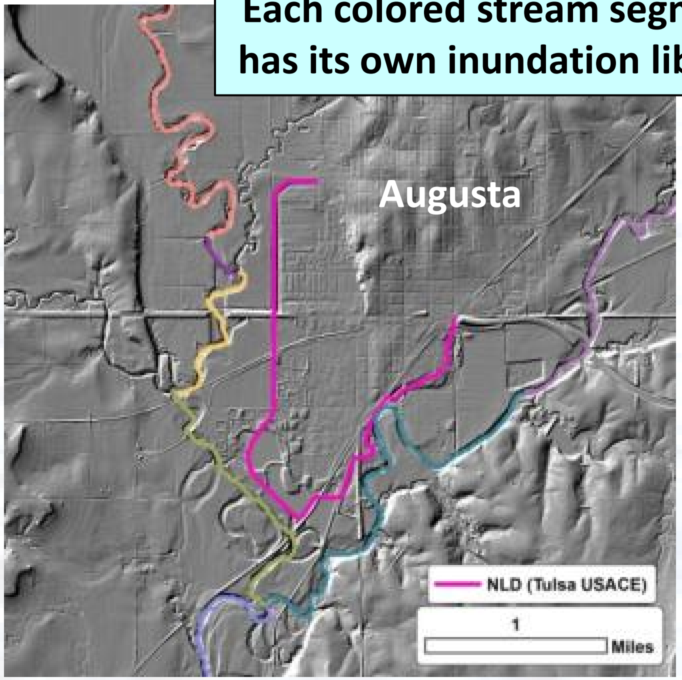
Example: Delaware River Basin above Perry Lake in northeast Kansas



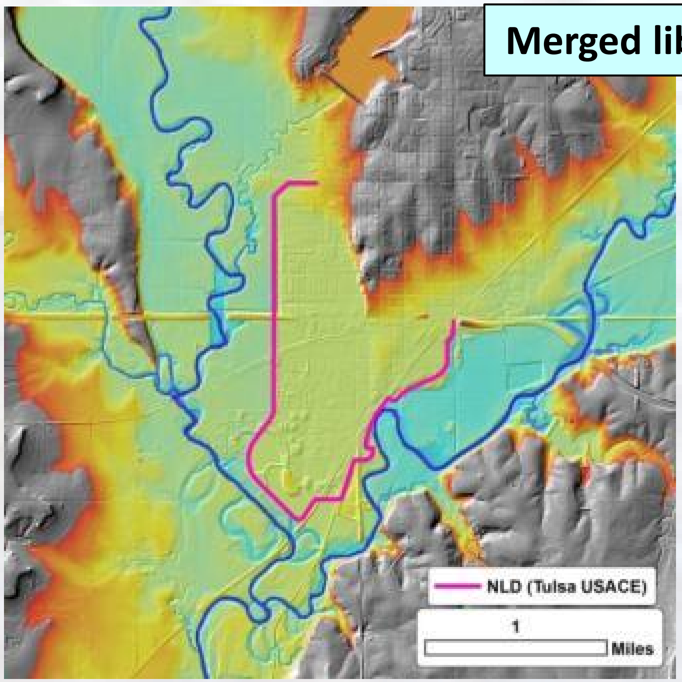
Example: Walnut River Basin in southeast Kansas



Each colored stream segment has its own inundation library

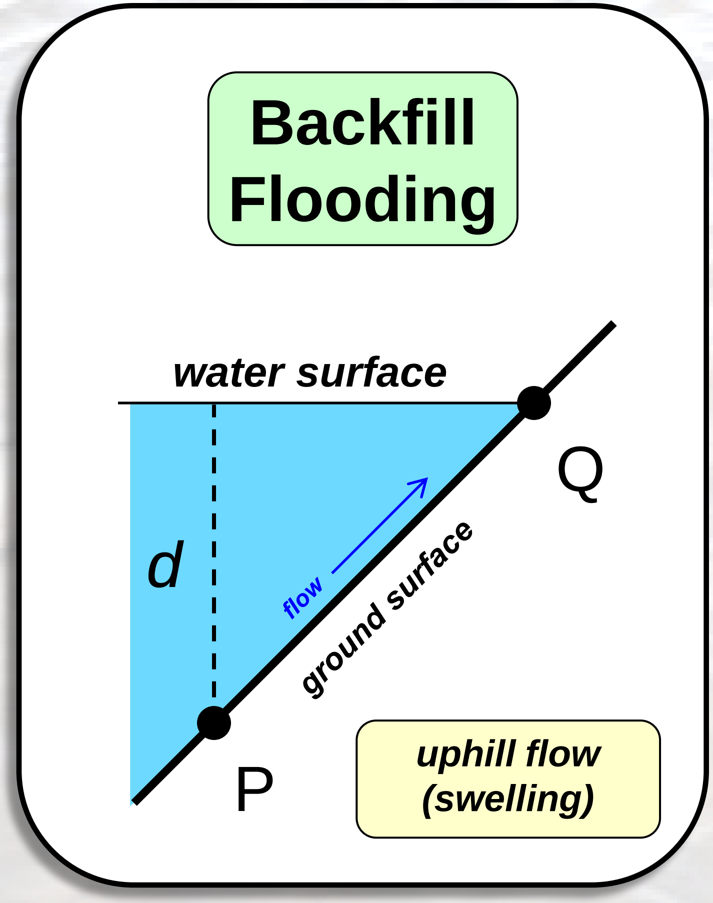


Merged library

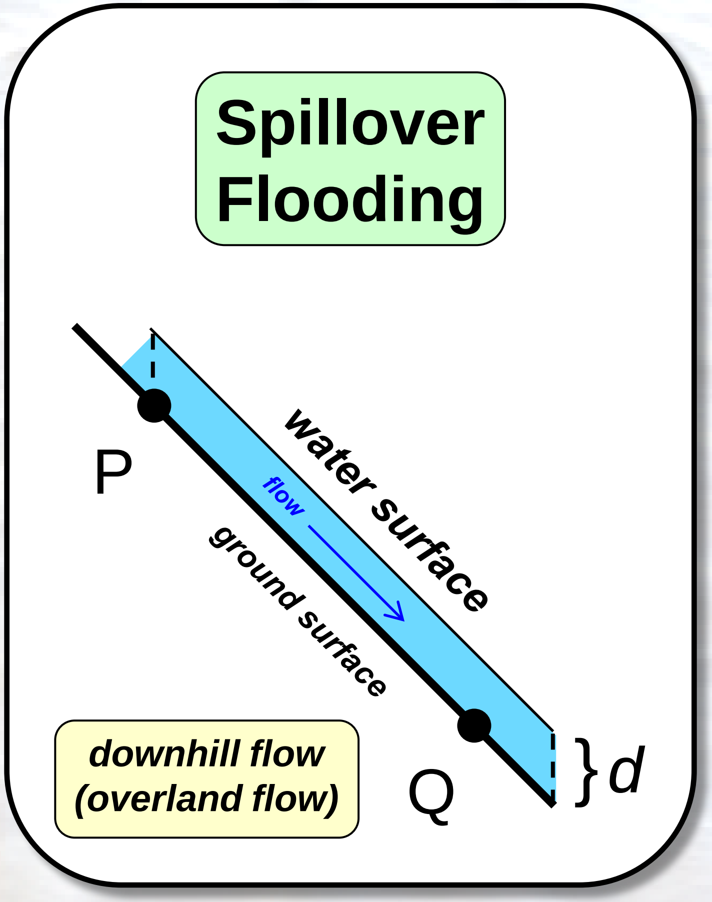


The FLDPLN ("Floodplain") Model—

There are two ways that point **Q** can be flooded by water originating from point **P**:

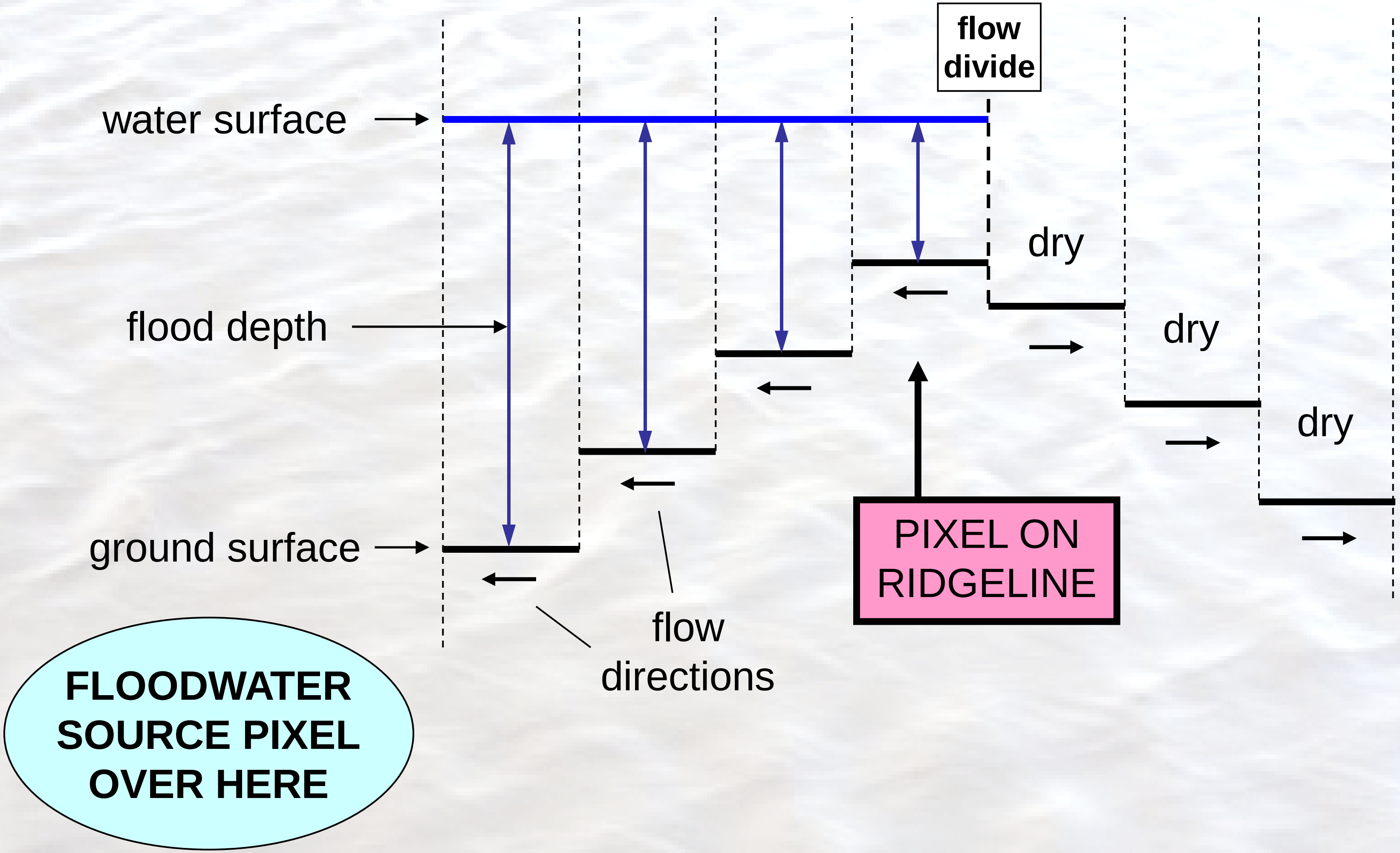


"Water seeks its own level"

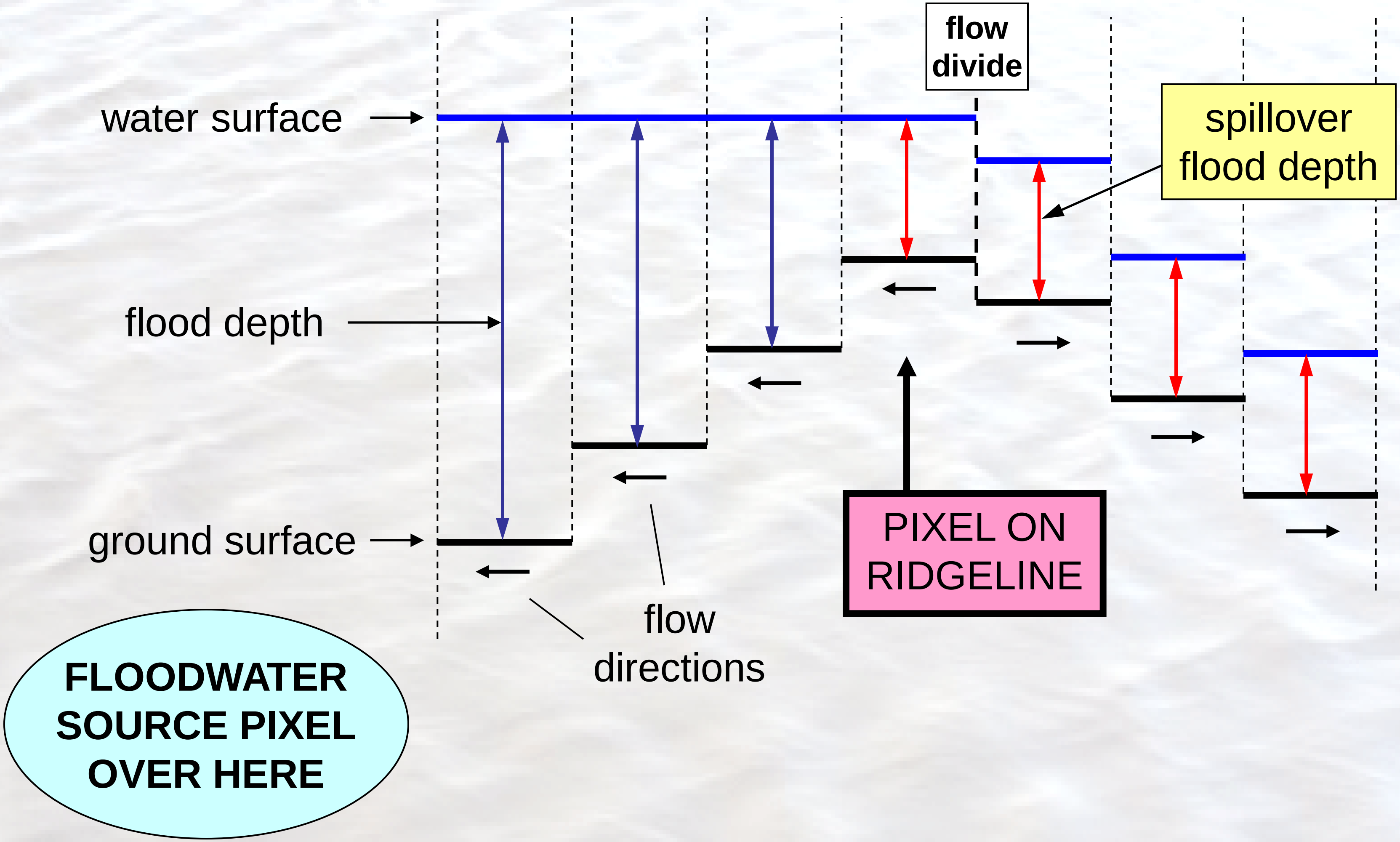


"Water flows downhill"

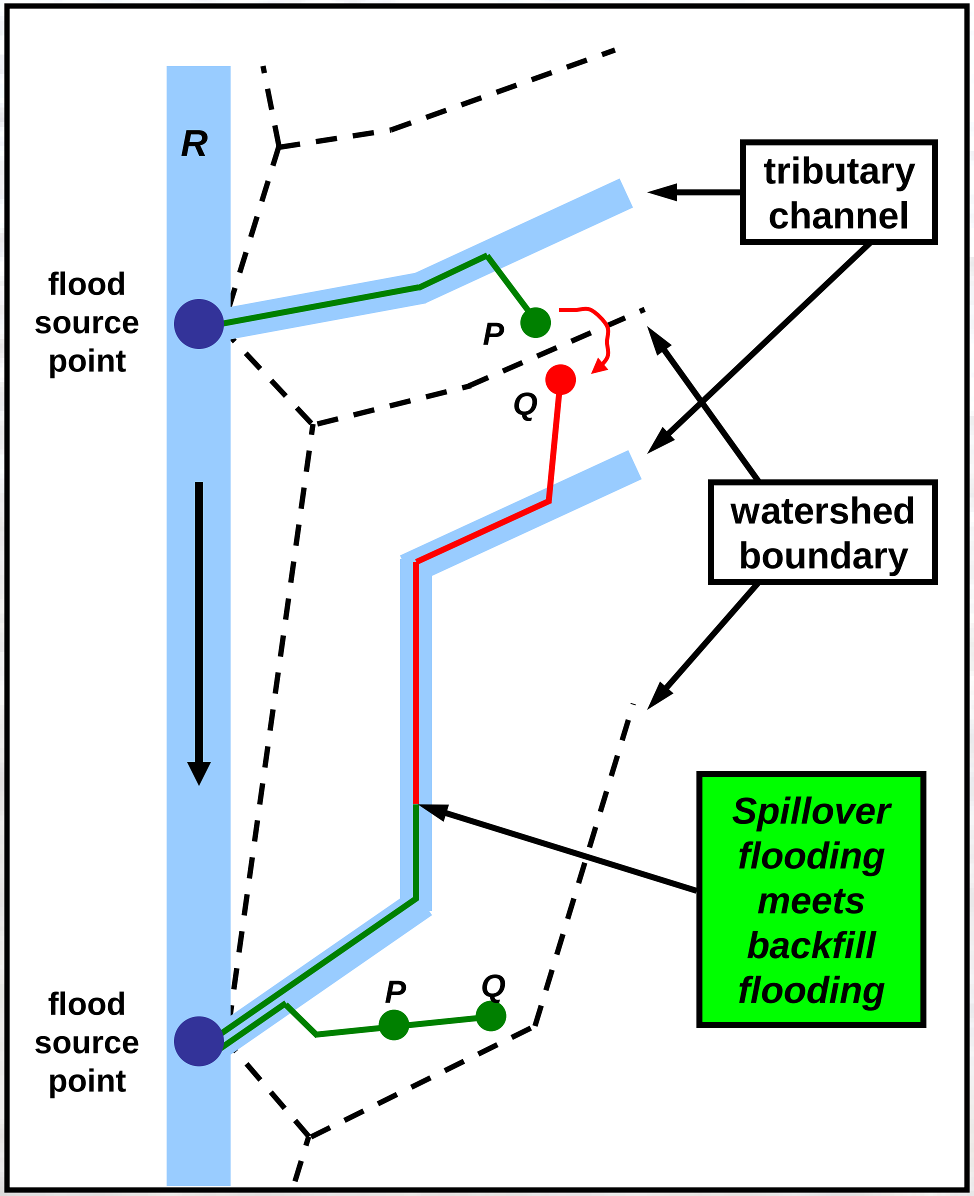
Backfill Flooding—accounts for floodwater expansion due to swelling processes

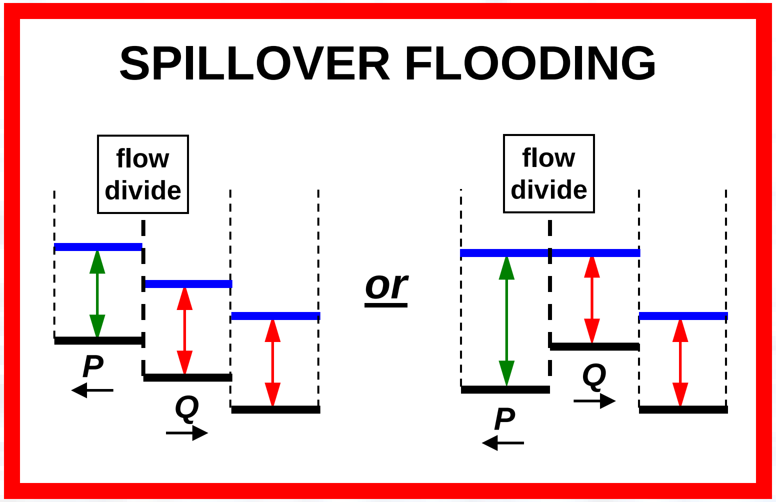


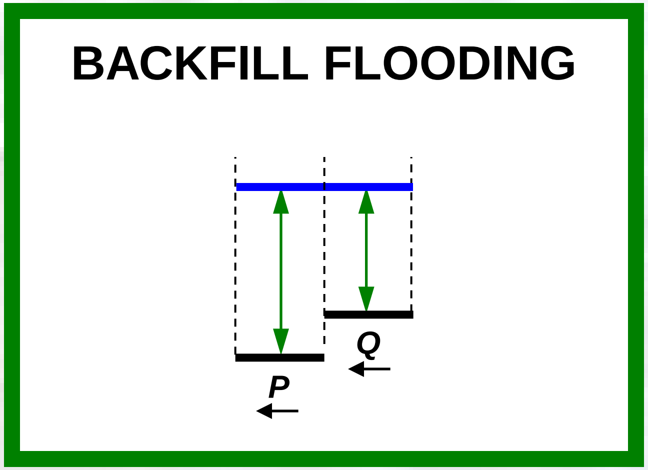
Spillover Flooding—accounts for floodwater rerouting (alternative flow path development)



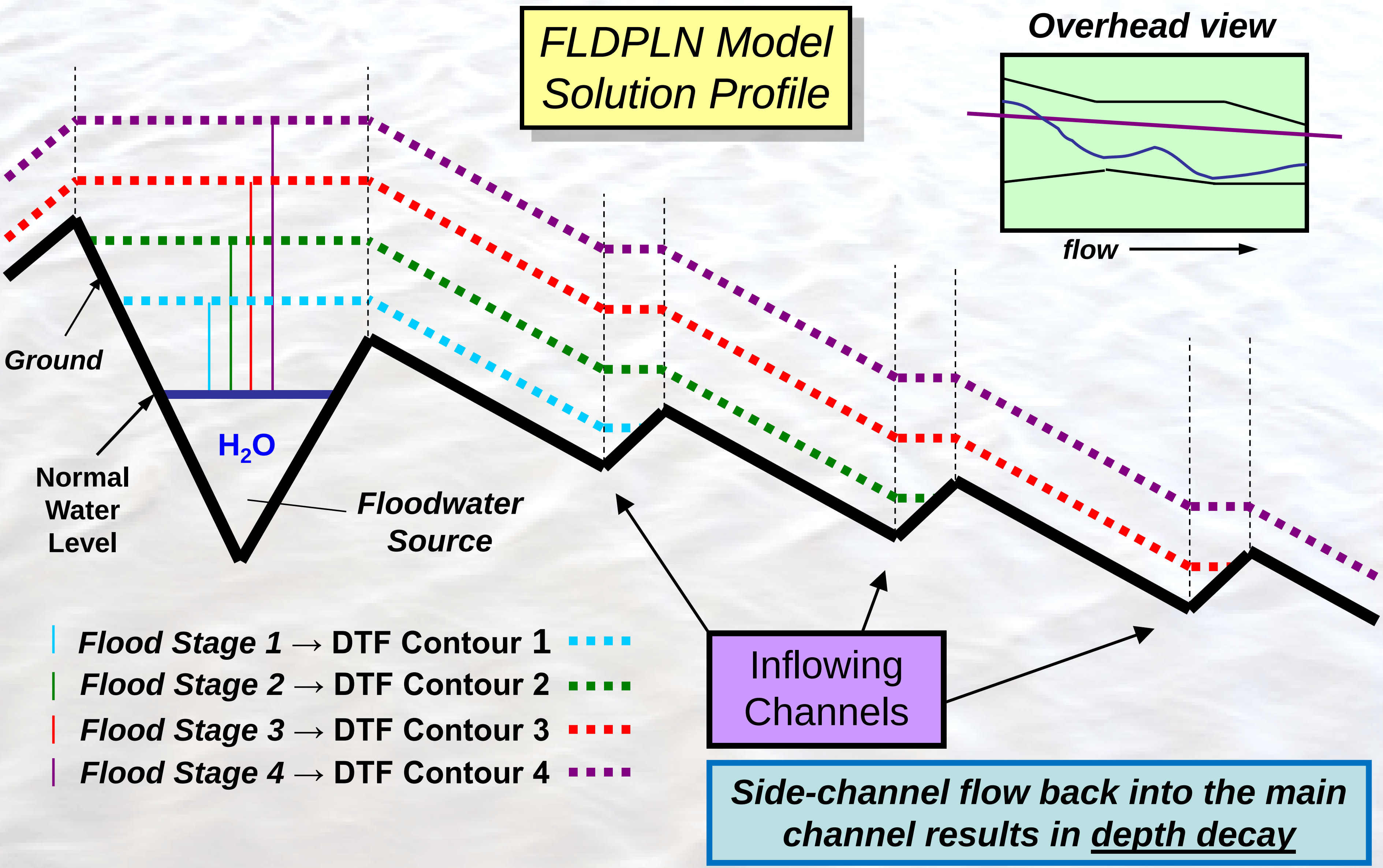
PLAN VIEW illustrating backfill and spillover flooding



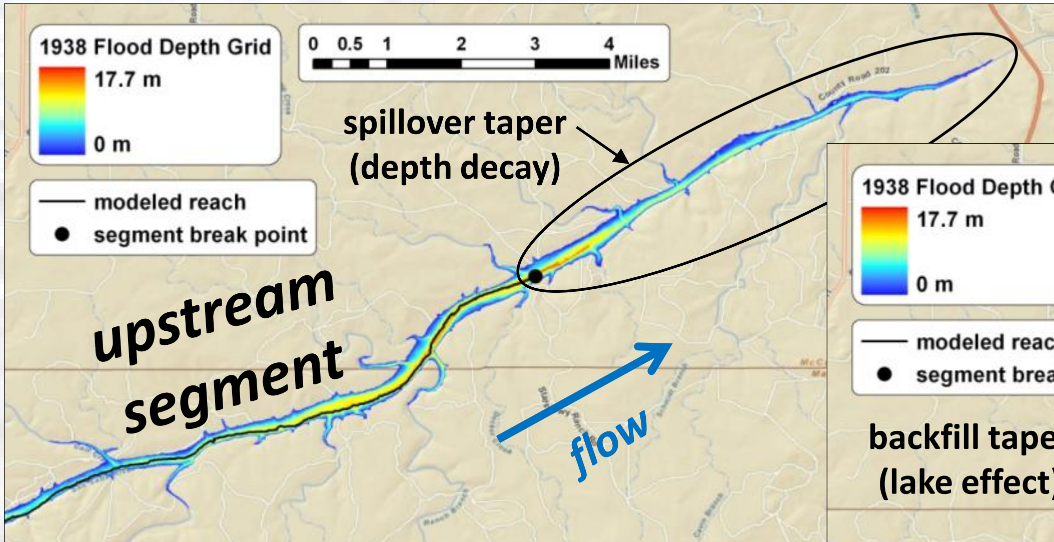


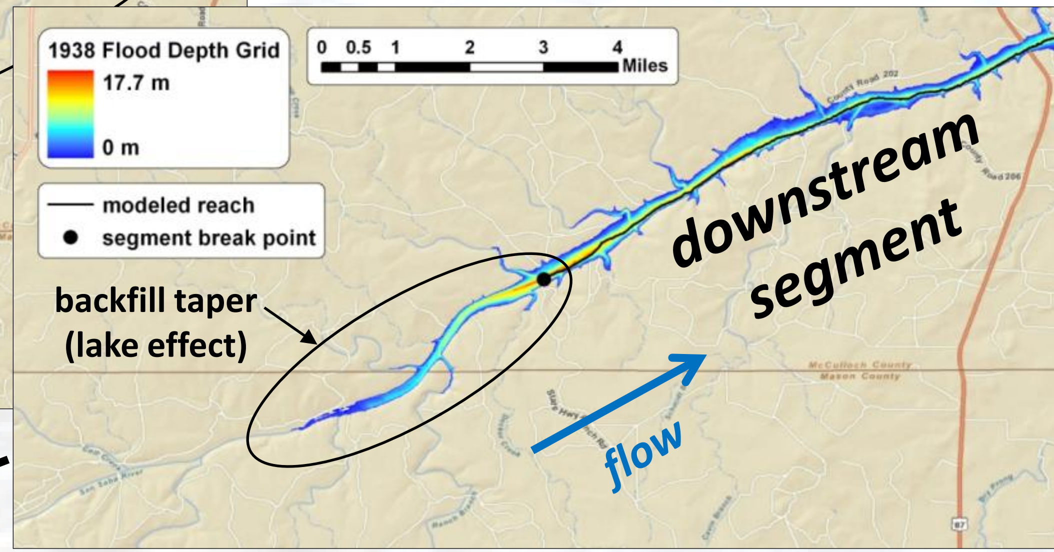


Longitudinal Floodplain Cross Section

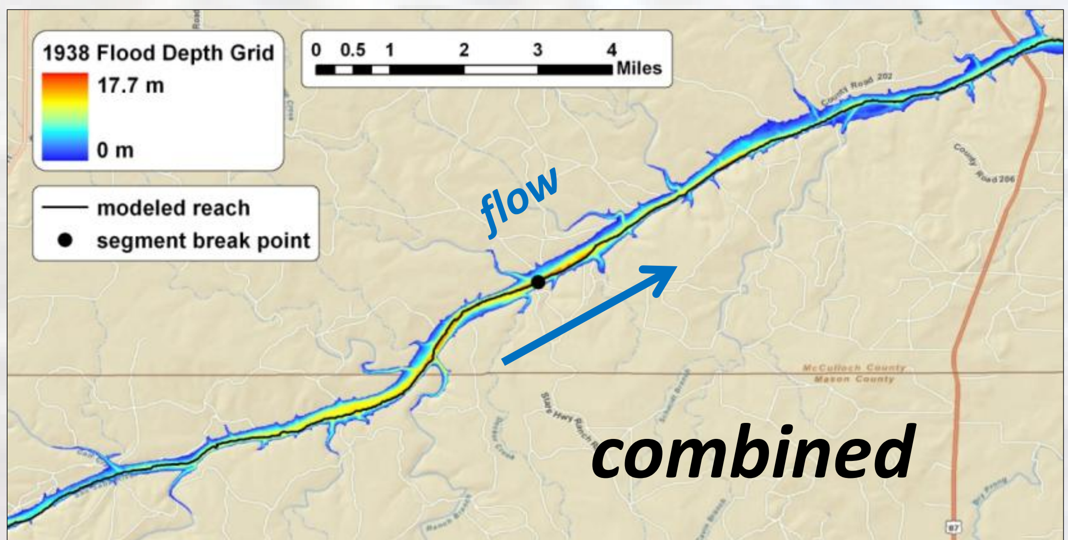


Seamless modeling with FLDPLN



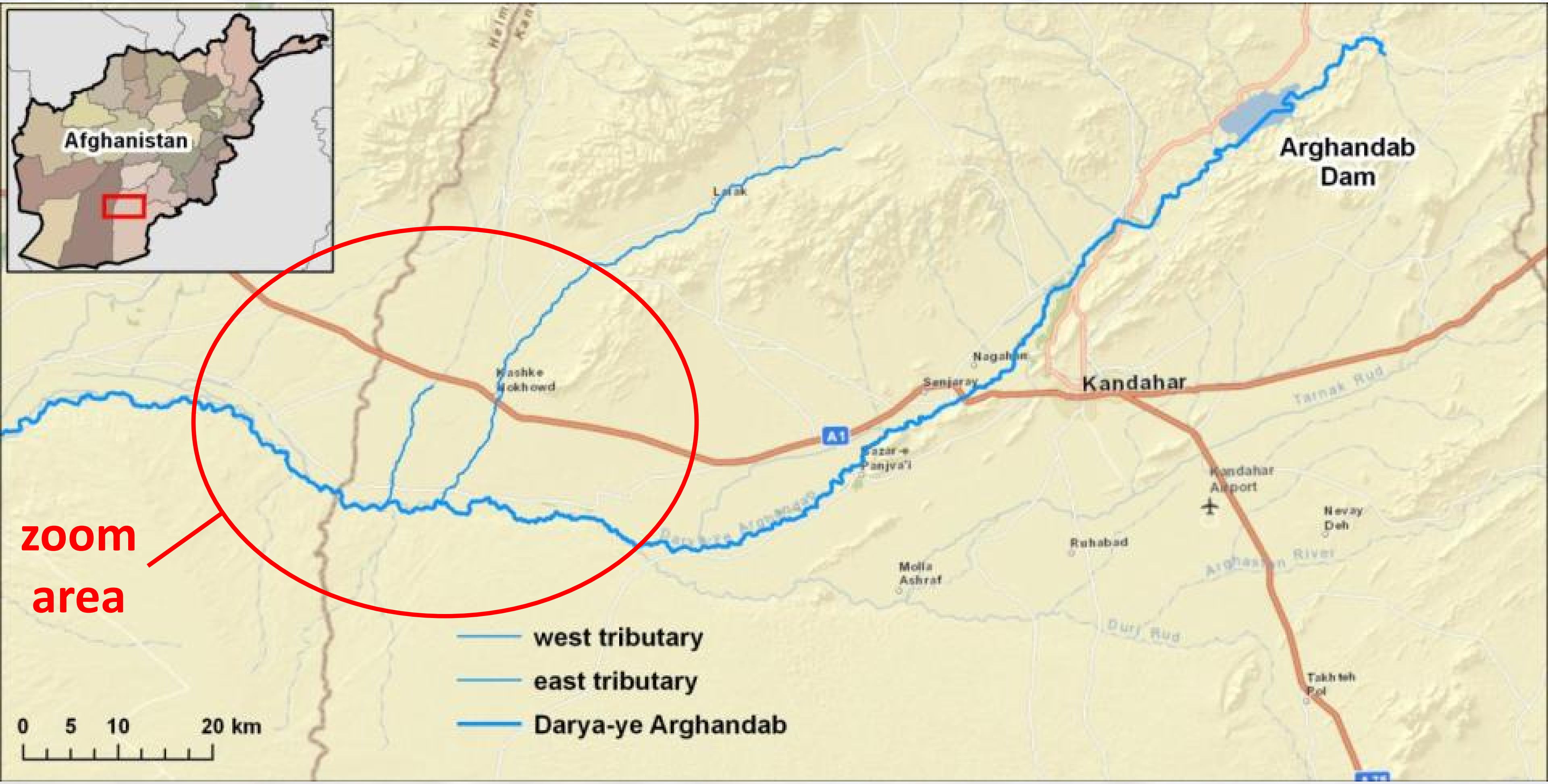


maximum value composite*

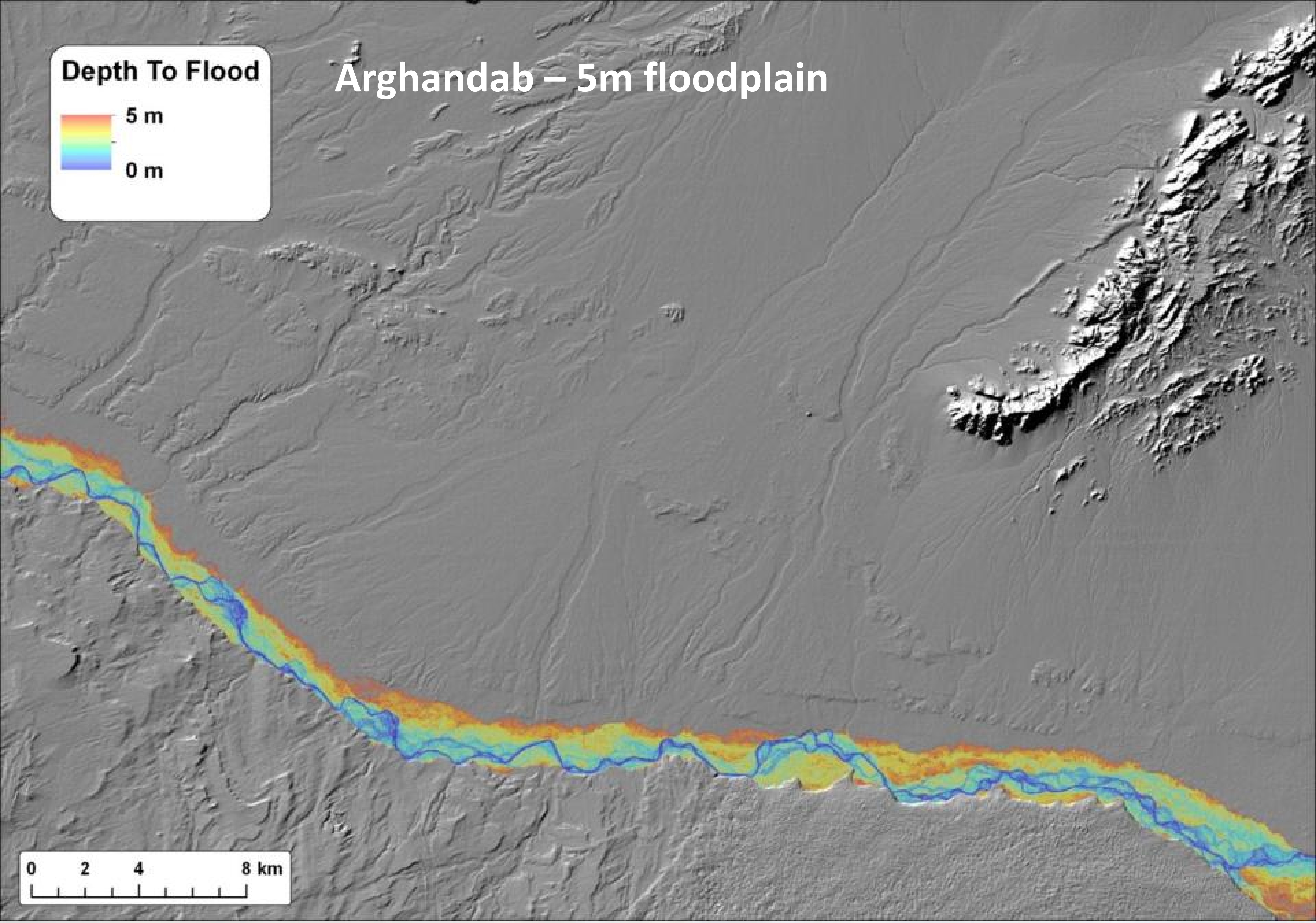


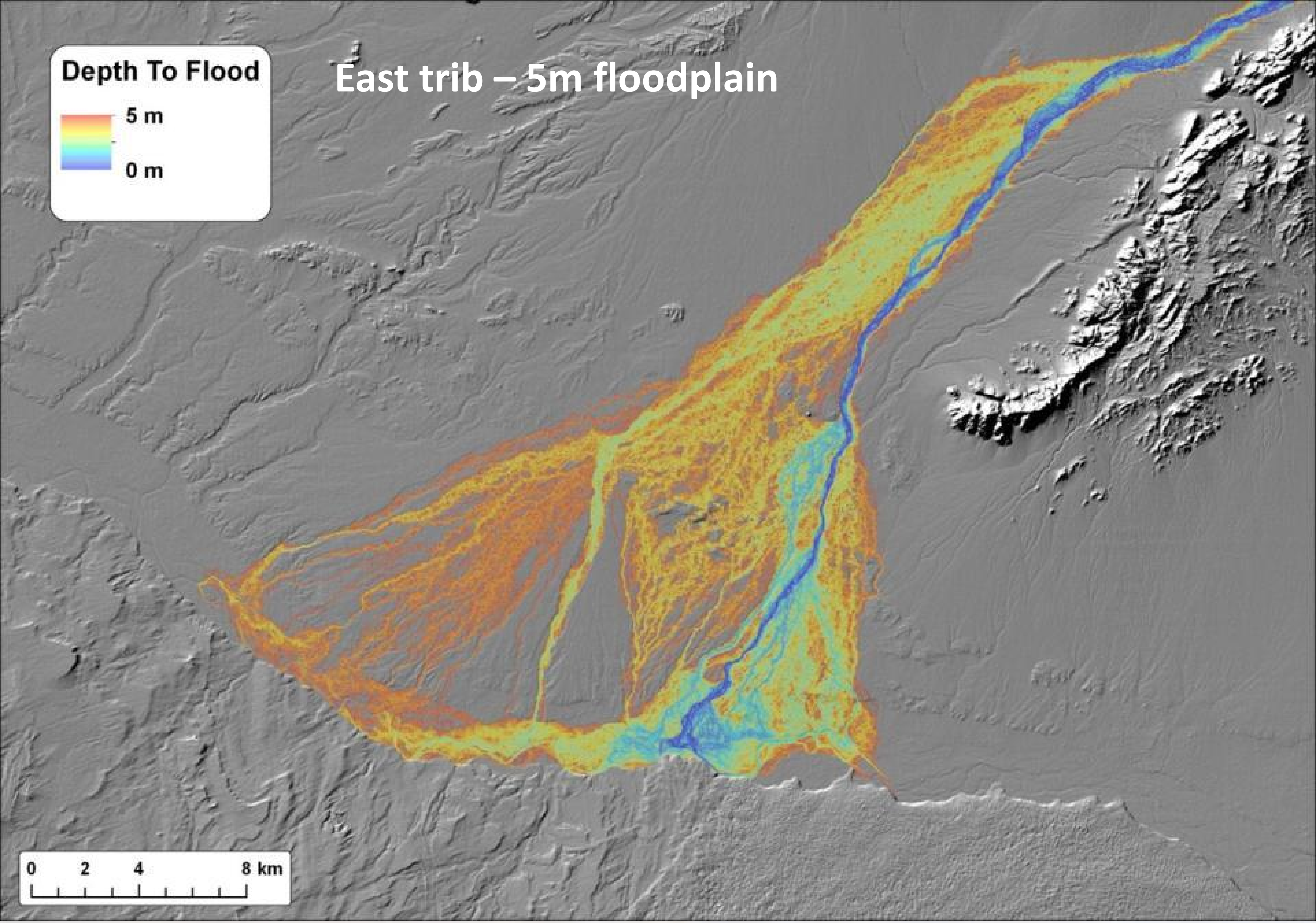
*Works for depth grids. Multi-segment merged DTF maps require minimum value compositing.

Seamless modeling with FLDPLN

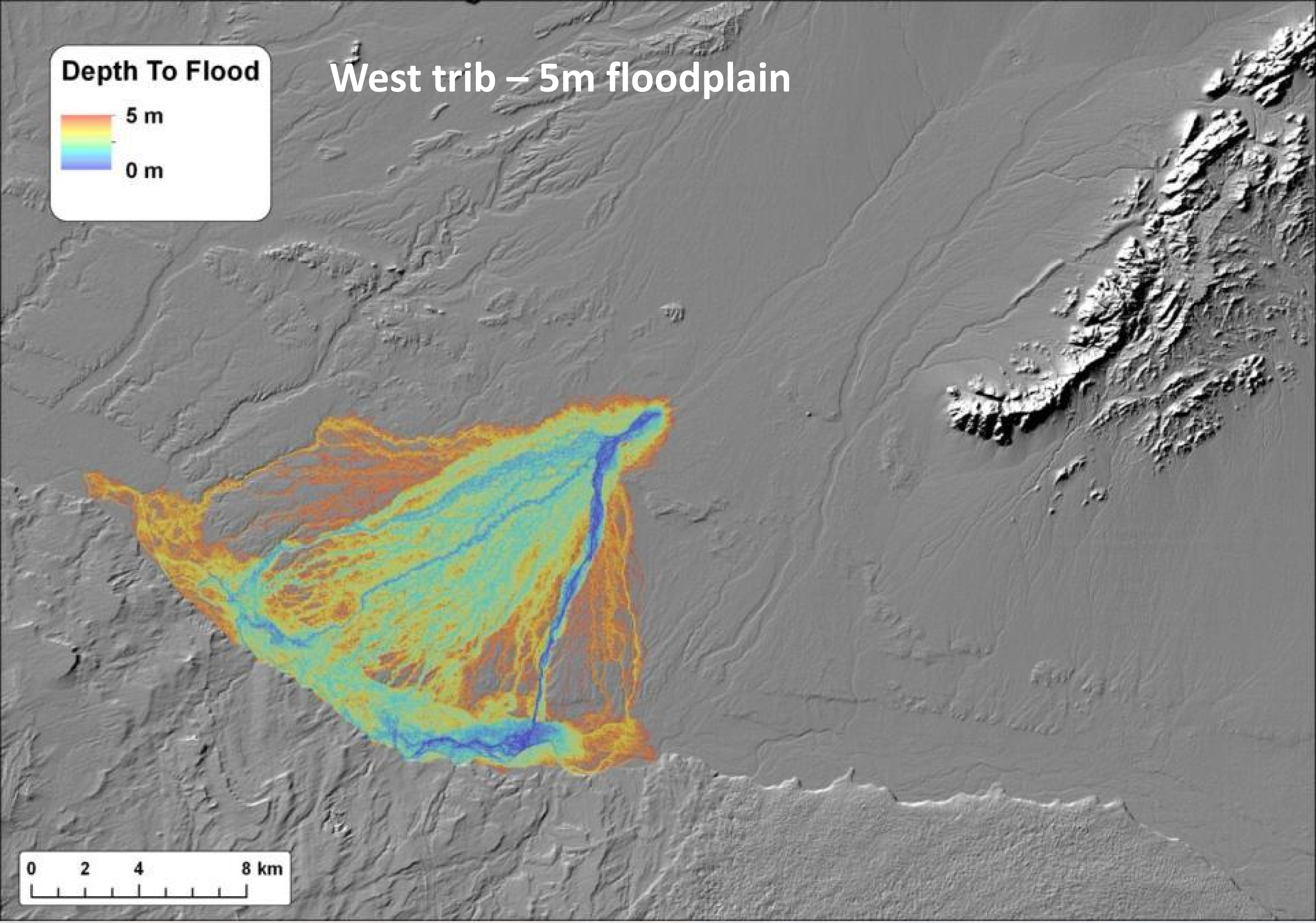


Arghandab – 5m floodplain

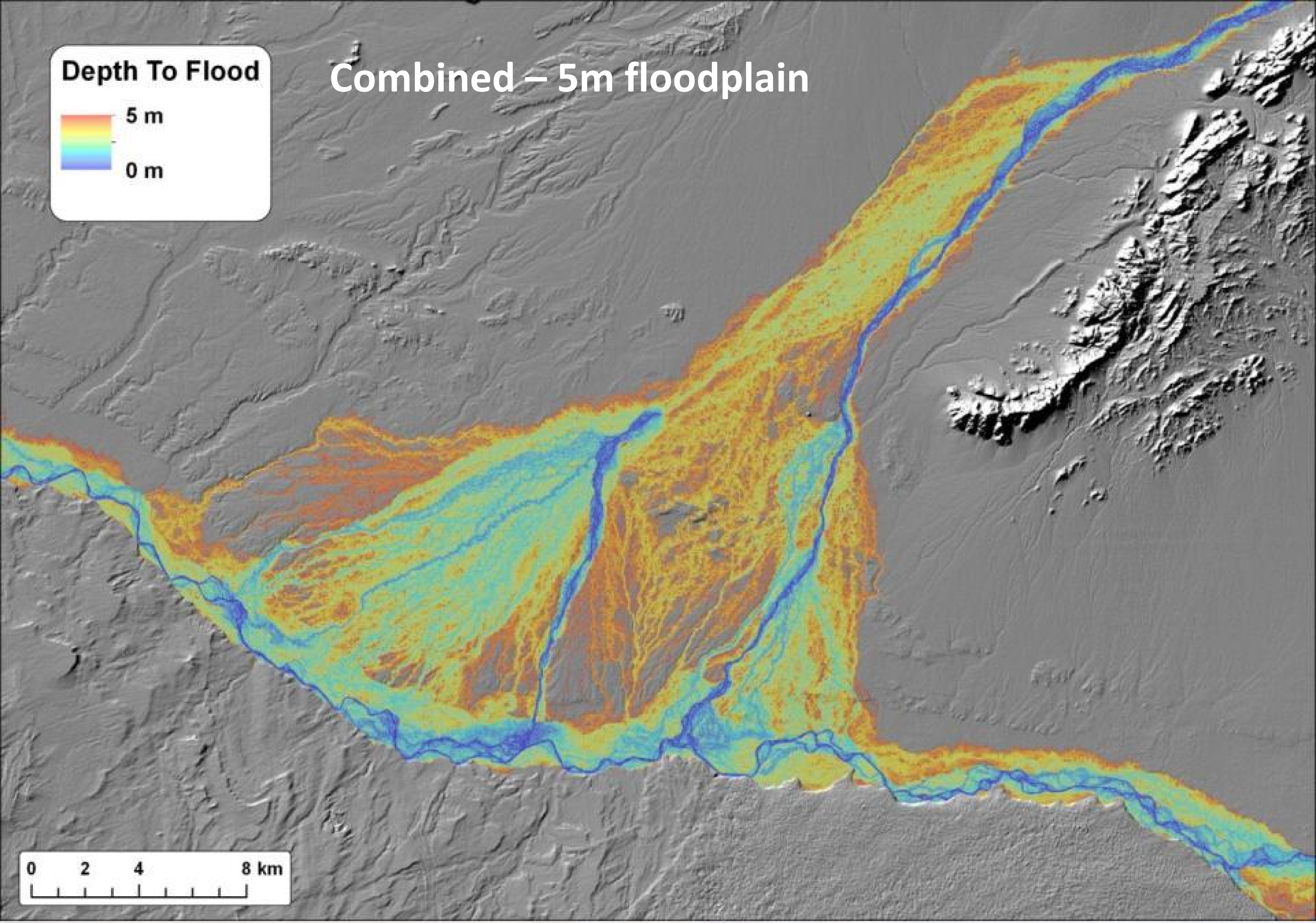



East trib – 5m floodplain
Depth To Flood
5 m
0 m
0
2
4
8 km

West trib – 5m floodplain

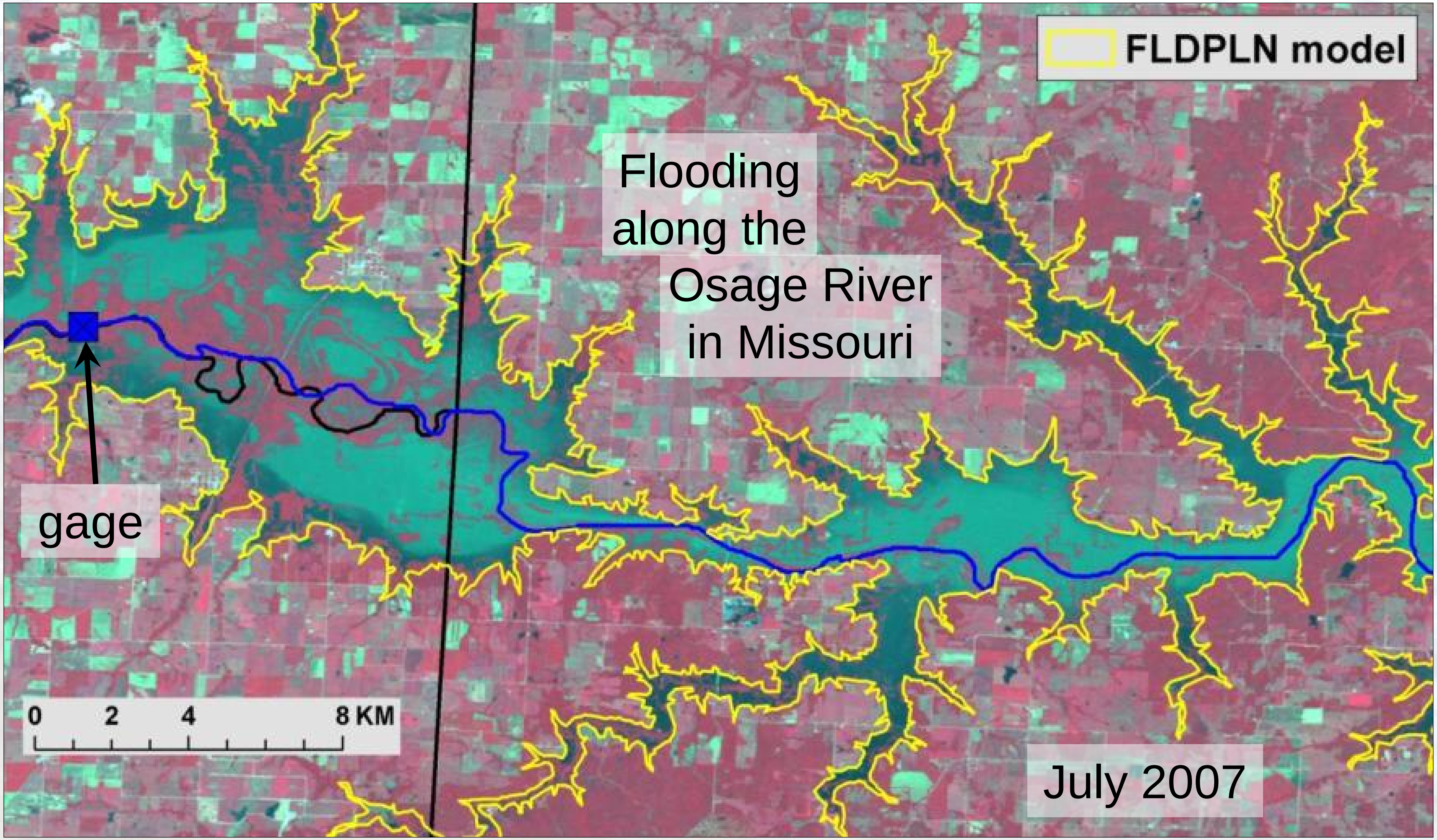


Combined – 5m floodplain



Now let's see some actual flood extent mapping…

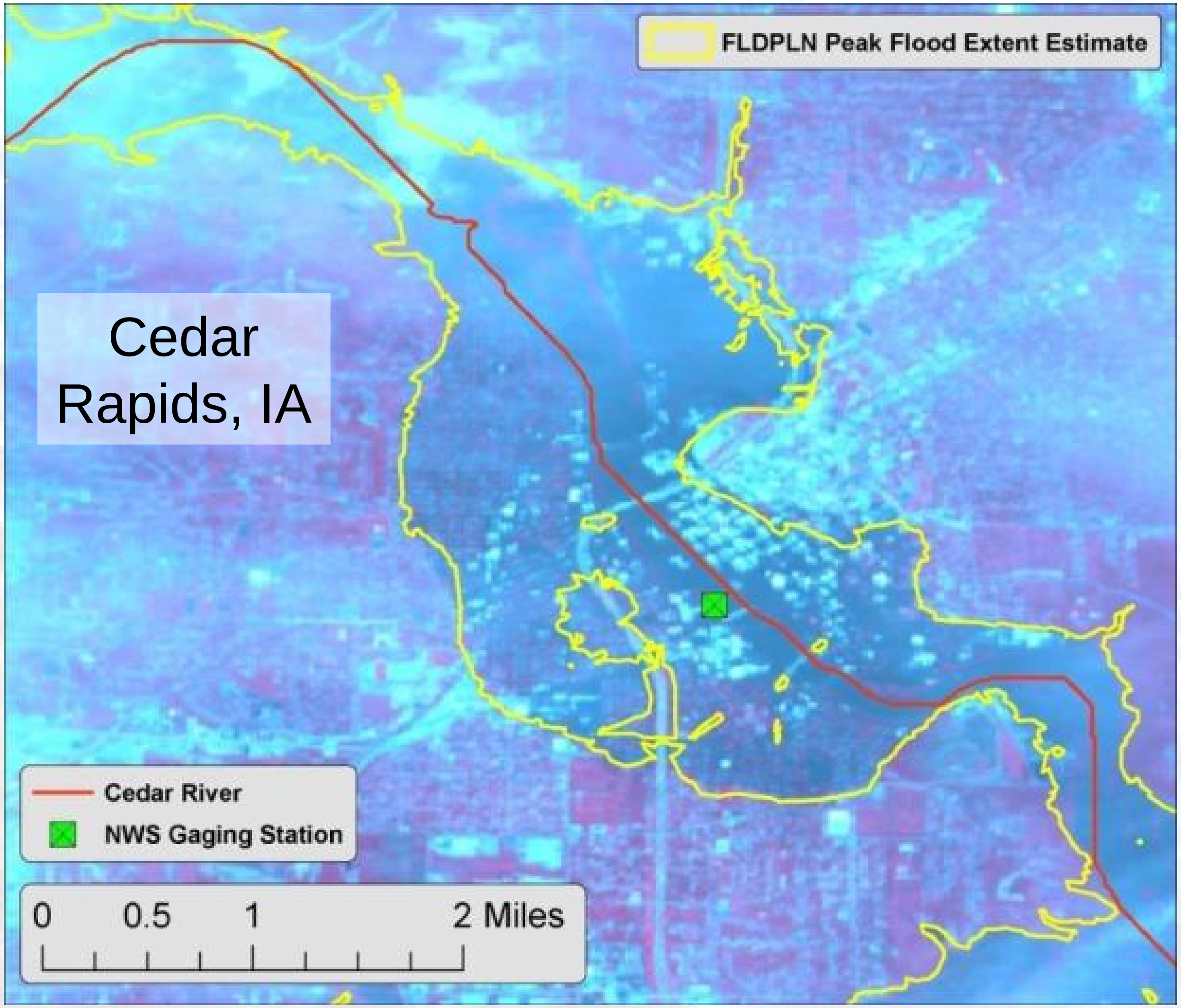
Flood Extent Estimation (Example 1)



Flood Extent Estimation (Example 2)

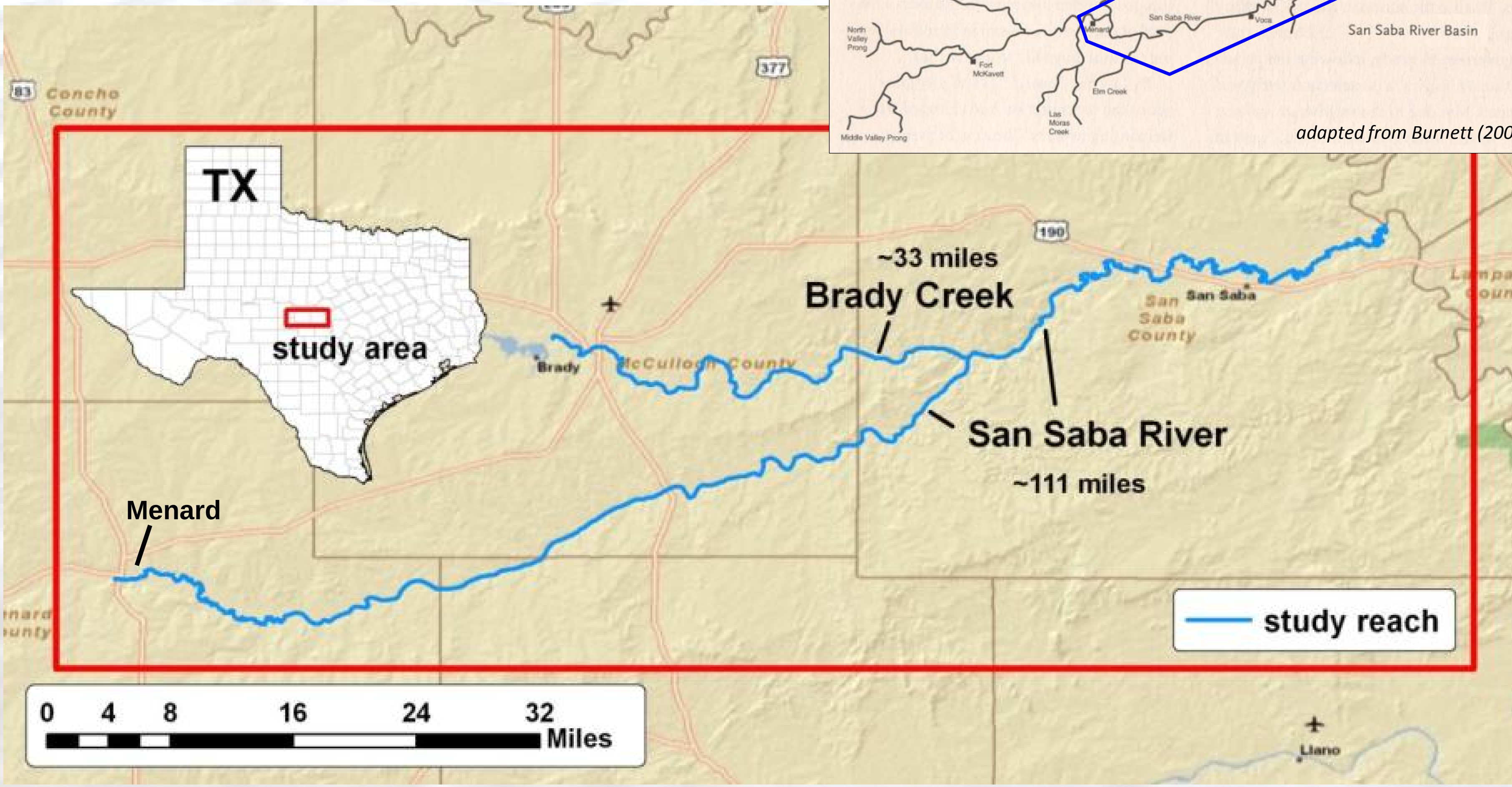
June 13, 2008

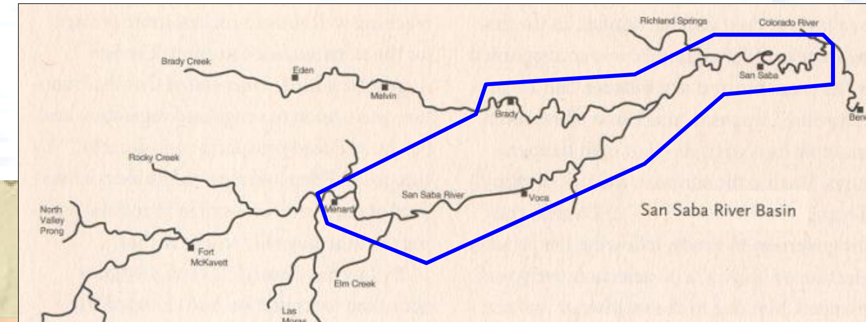
Flooding on the Cedar River crested more than 11 ft above the historic record in Cedar Rapids, Iowa



Example 3:

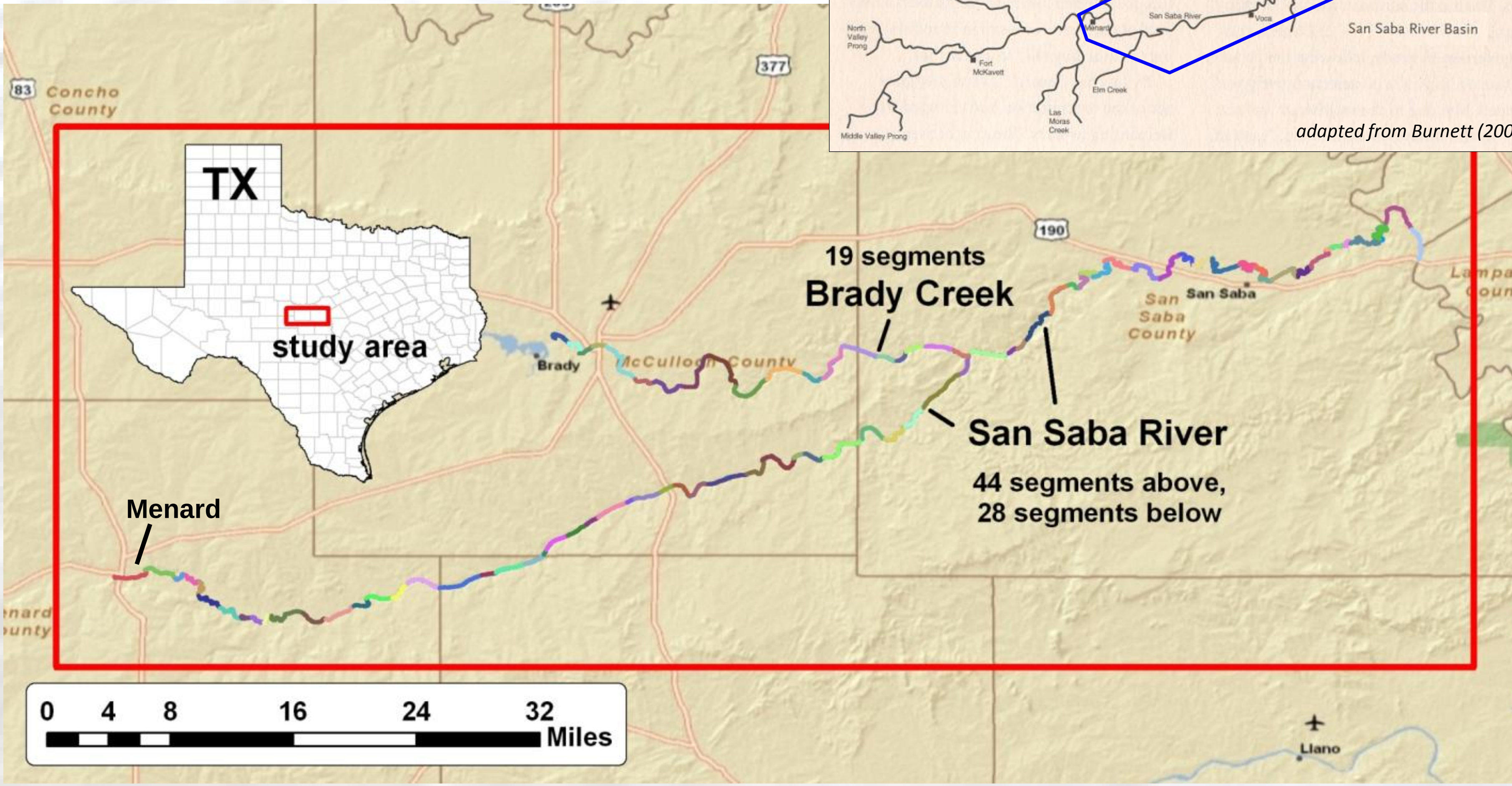
1938 Texas Flood Study Area

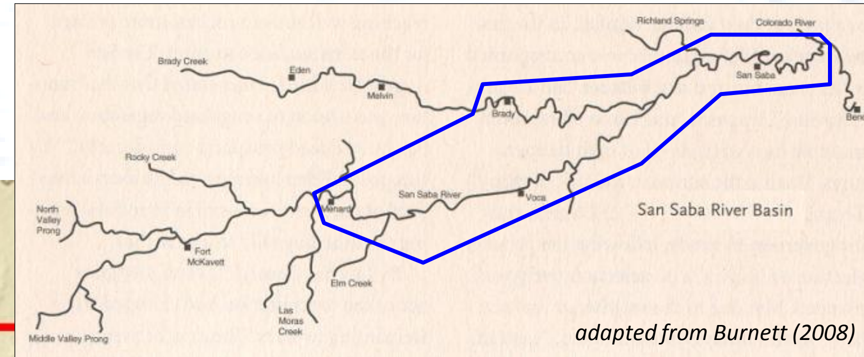




adapted from Burnett (2008)

Analyzed Stream Segments





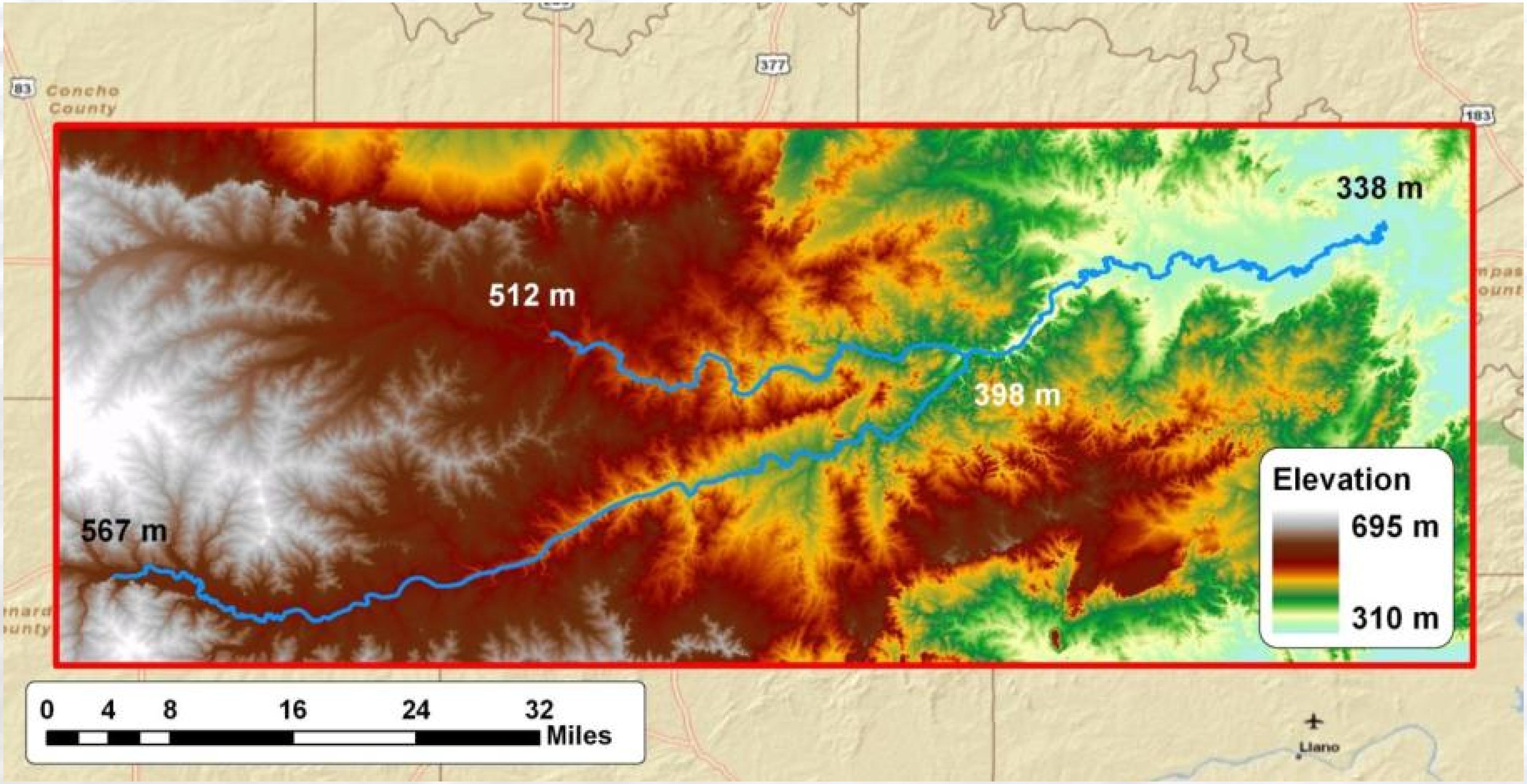
adapted from Burnett (2008)

FLDPLN can be applied using <u>any</u> stream segmentation.

For this analysis, the study reach was initially partitioned at all confluences with tributary catchments > 2 sq mi.

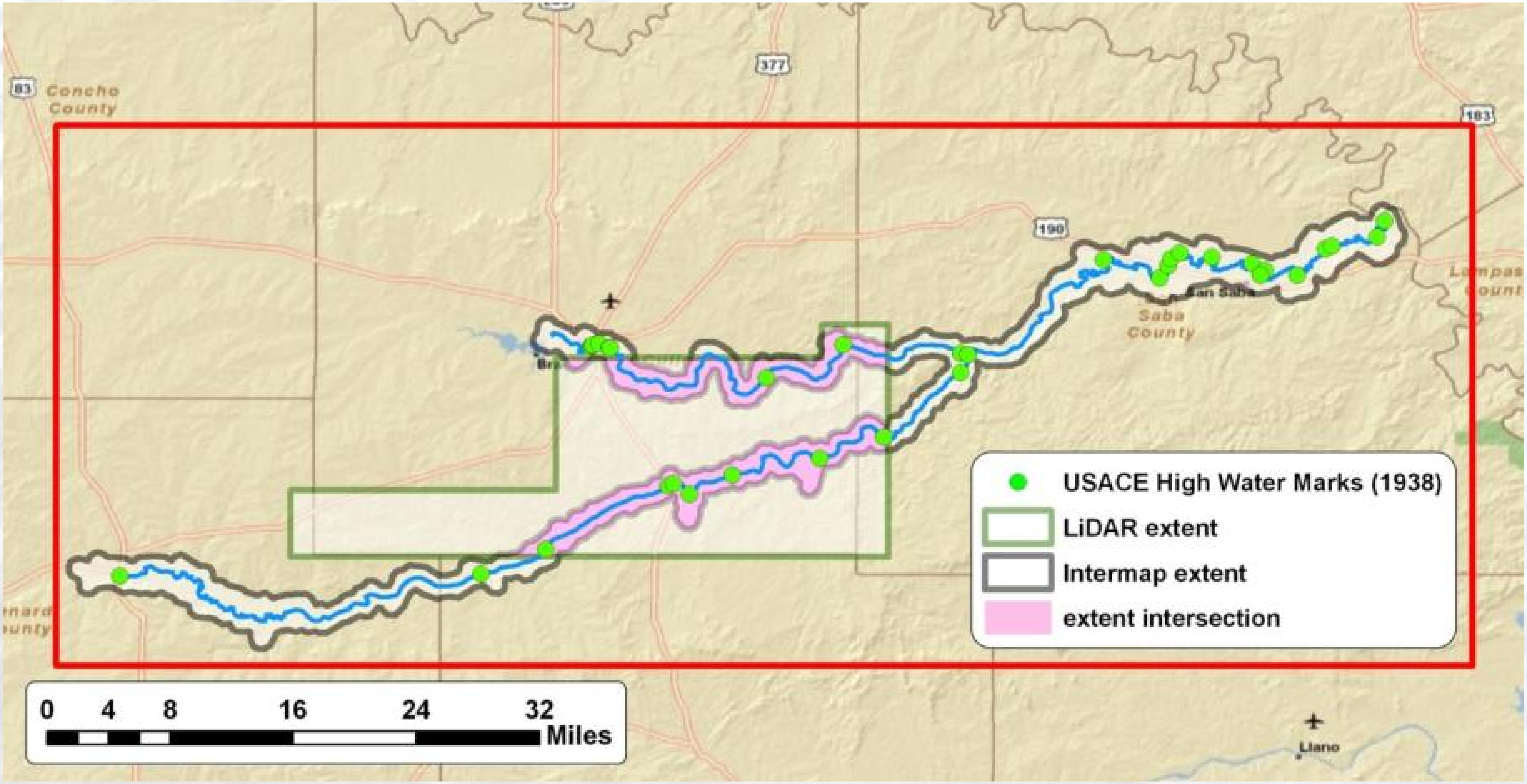
All spans > 5 km in length were further subdivided at maximum flow accumulation change points.

NED Elevation



10-m Elevation data from USGS National Elevation Dataset (NED)

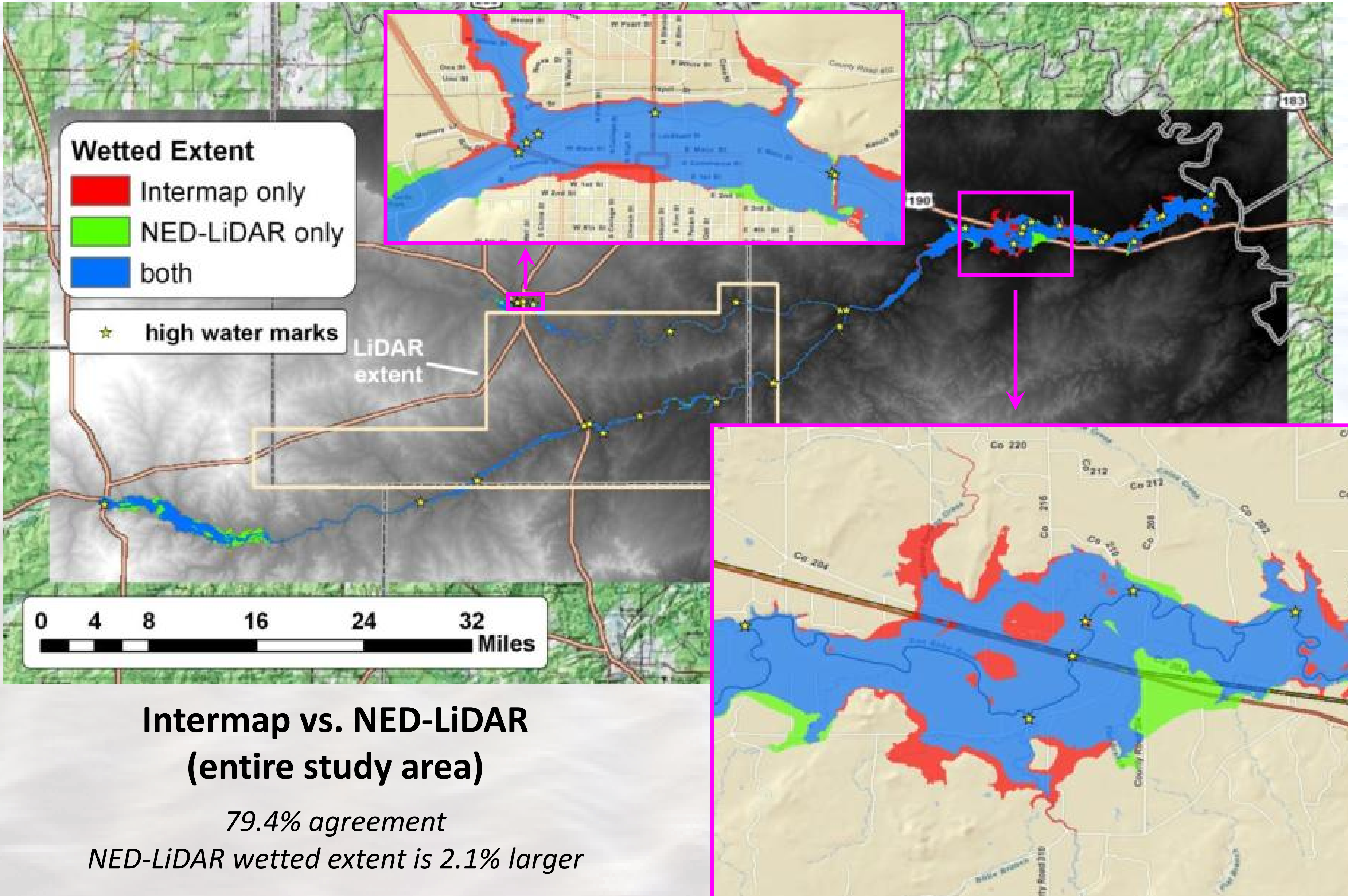
Other Elevation Data



Additionally, <u>LiDAR</u> elevation data were provided by TNRIS.
Intermap also kindly provided <u>IfSAR</u> elevation data to improve the analysis.

Both were downsampled to the 10-m NED grid before processing.

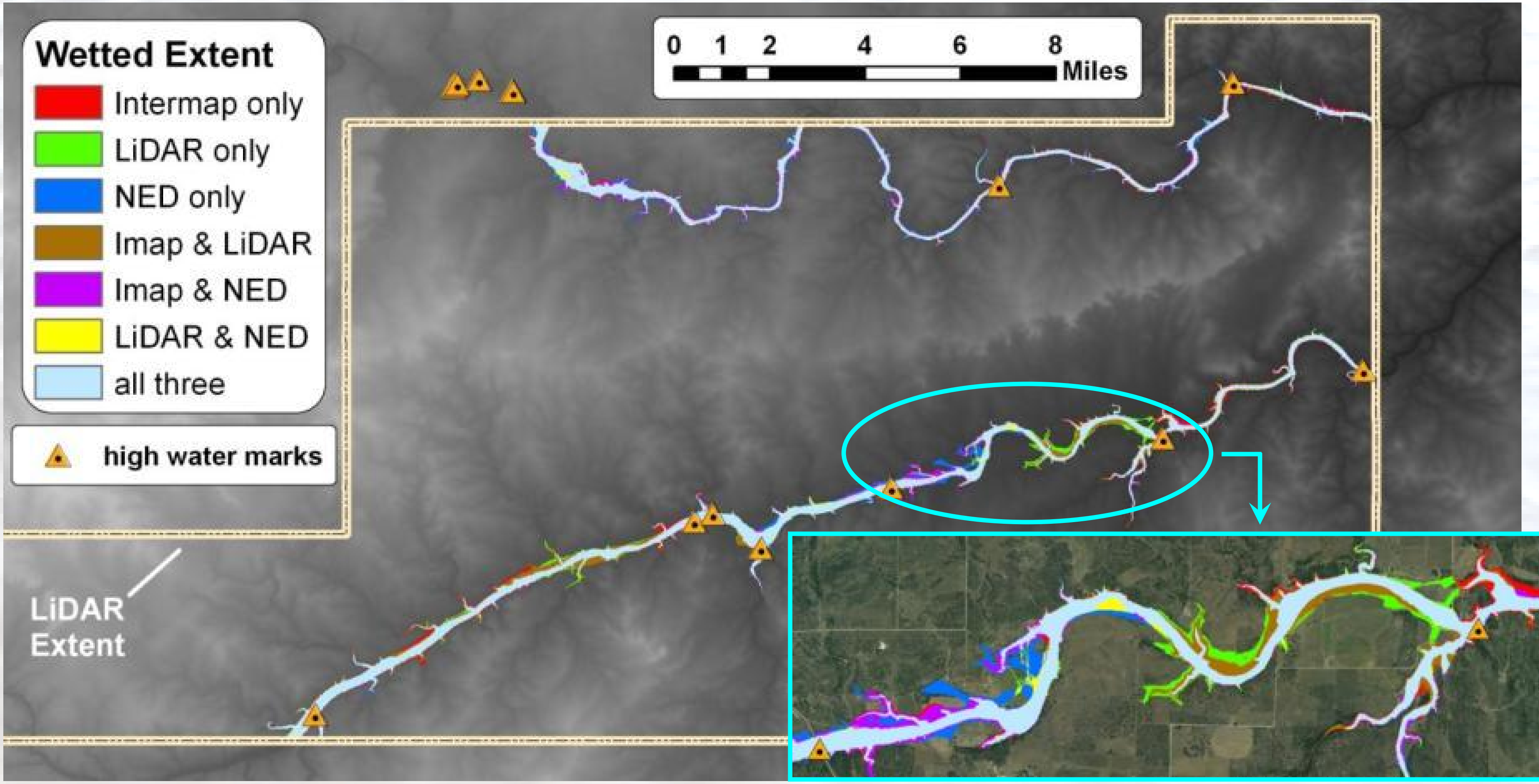
Wetted Extent Correspondence



Intermap vs. NED-LiDAR (entire study area)

79.4% agreement
NED-LiDAR wetted extent is 2.1% larger

Wetted Extent Correspondence

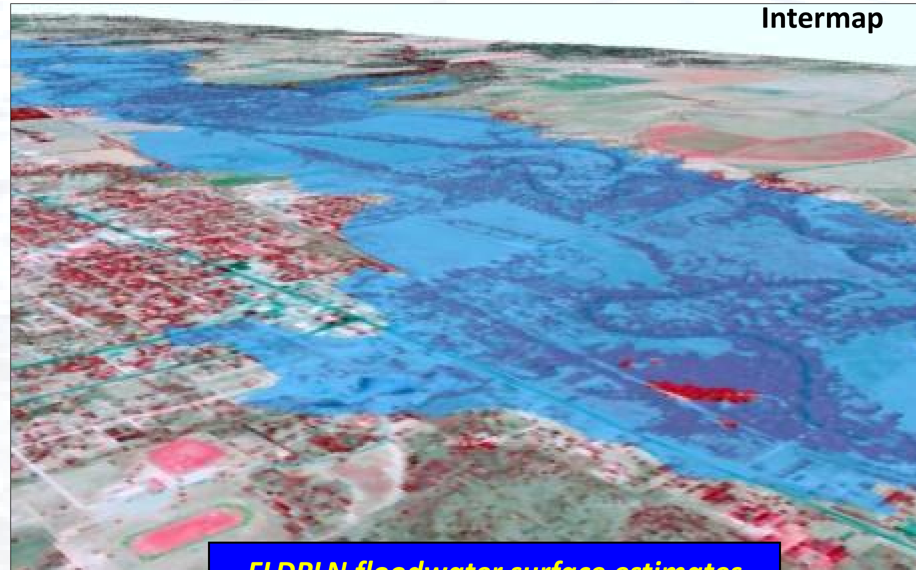


Intermap vs. LiDAR vs. NED (LiDAR area only)

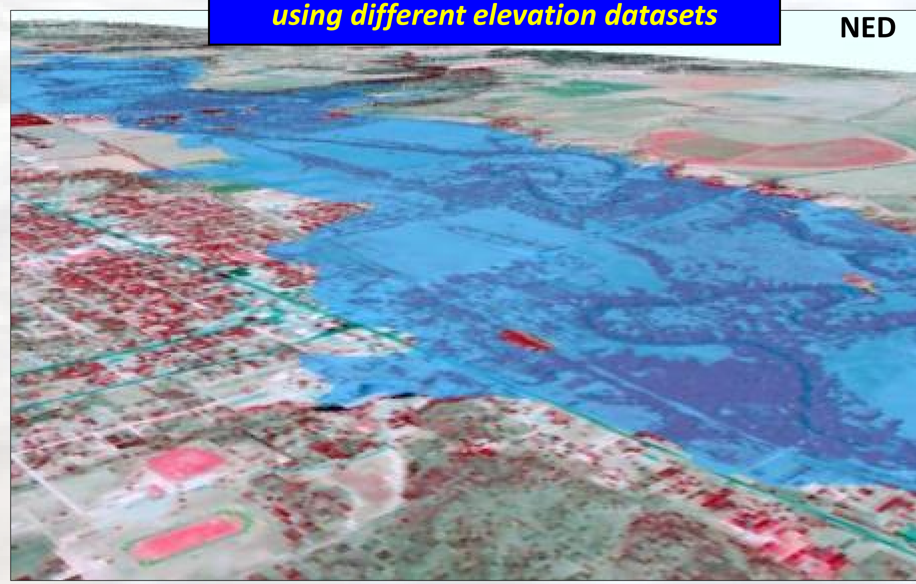
Intermap agreement:	82.8% [L-N union]	80.8% [Lidar]	76.5% [NED]
LiDAR agreement:	77.2% [I-N union]	72.7% [NED]	
NED agreement:	75.4% [I-L union]		

Example 3 – Verification

*Oblique aerial photo over **San Saba, Texas,** during a record flood that occurred in **July 1938**.*



FLDPLN floodwater surface estimates using different elevation datasets



High water marks collected by the USACE in 1938 were used to model this event.

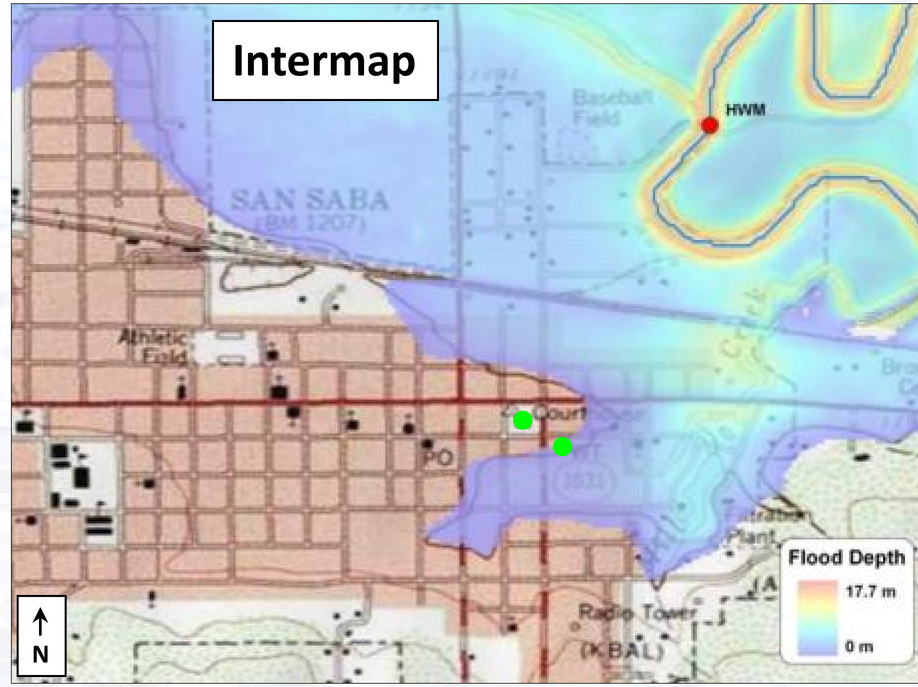
Example 3 (continued)

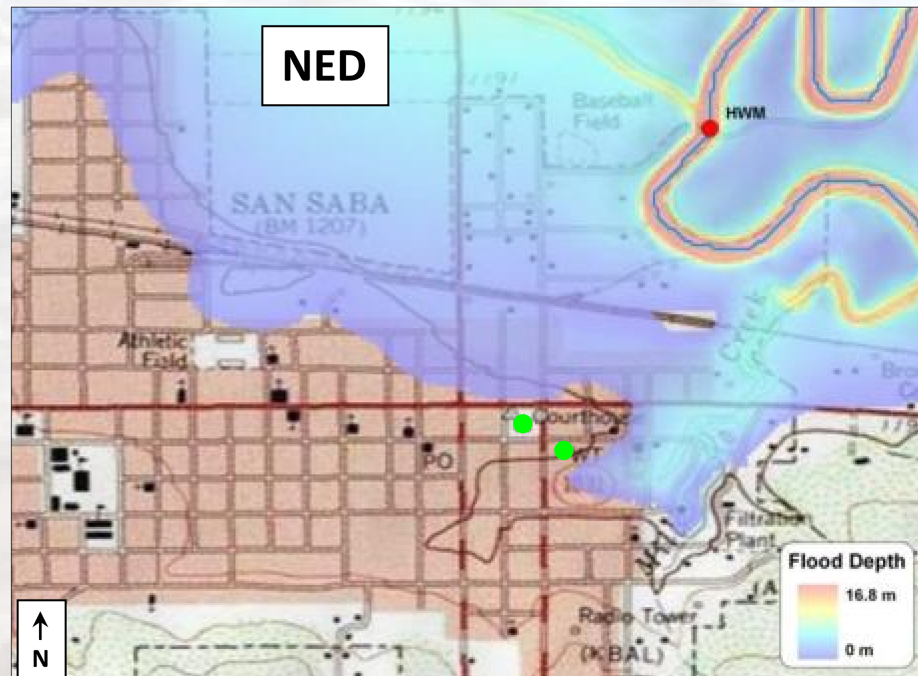
Oblique aerial photo of San Saba during the 1938 flood (not necessarily at crest).

Note the locations of the water tower & the courthouse (green dots).

"Reports and pictures in the Dallas Morning News, The Saba News and Star, and the Wichita Falls Record News show that in the City of San Saba, flood waters from the river spread through a great part of the business district and around the courthouse and spread over more than one-third of the City."

-- excerpt from
http://www.texashillcountry.com/san-saba-texas/san-saba-texas.php

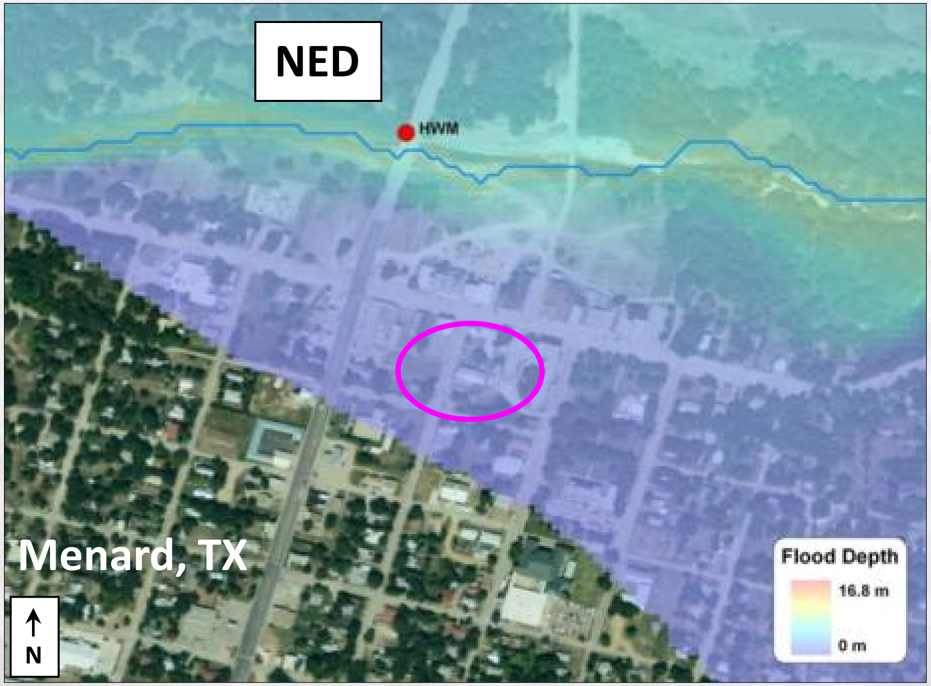




Example 3 (continued)

Water reached a depth of five feet in the Mission Theater and one foot in the Bevans Hotel in Menard.

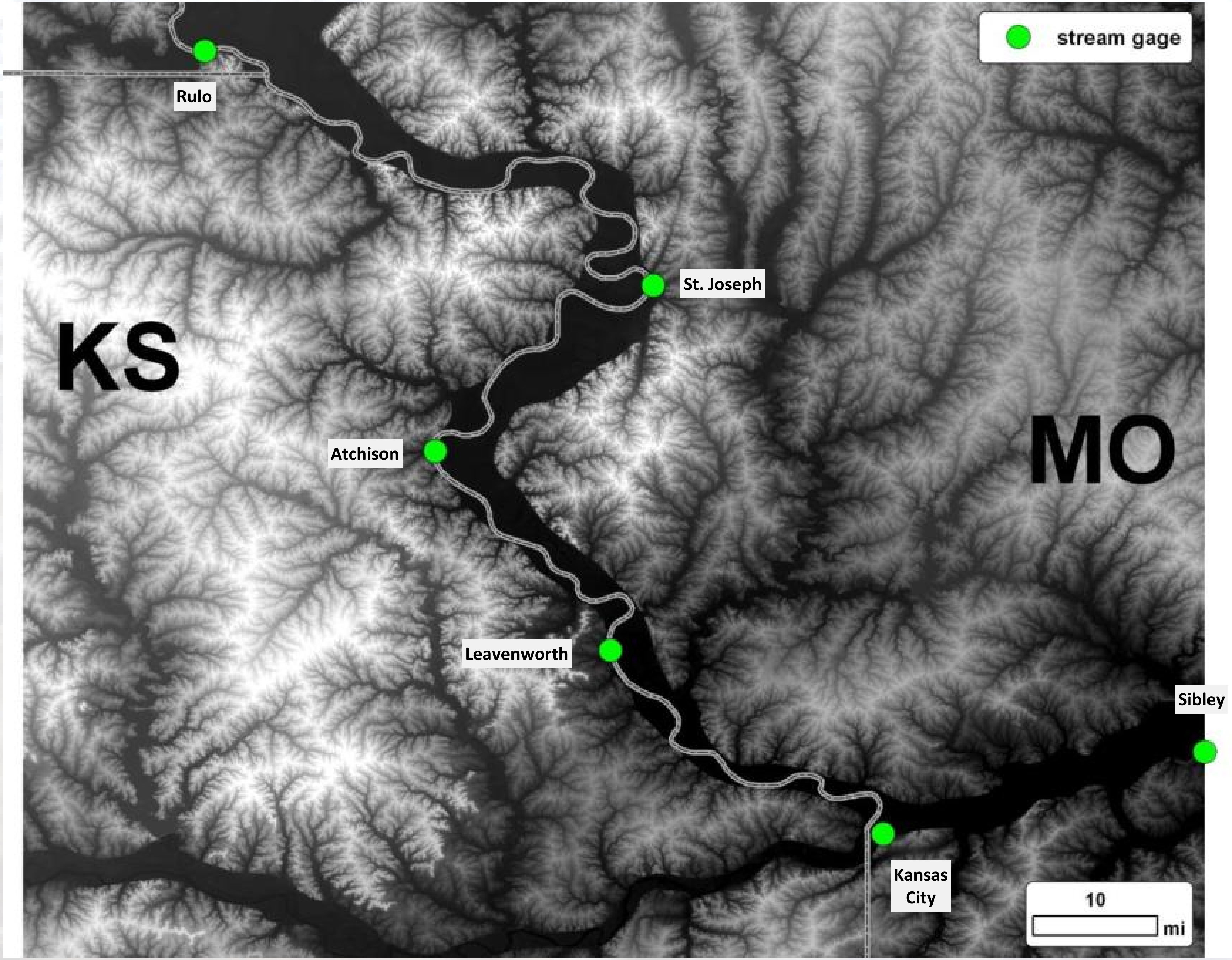
Both Intermap and NED 1938 flood simulations indicate a flood depth of 2-3 ft in Mission Theatre.

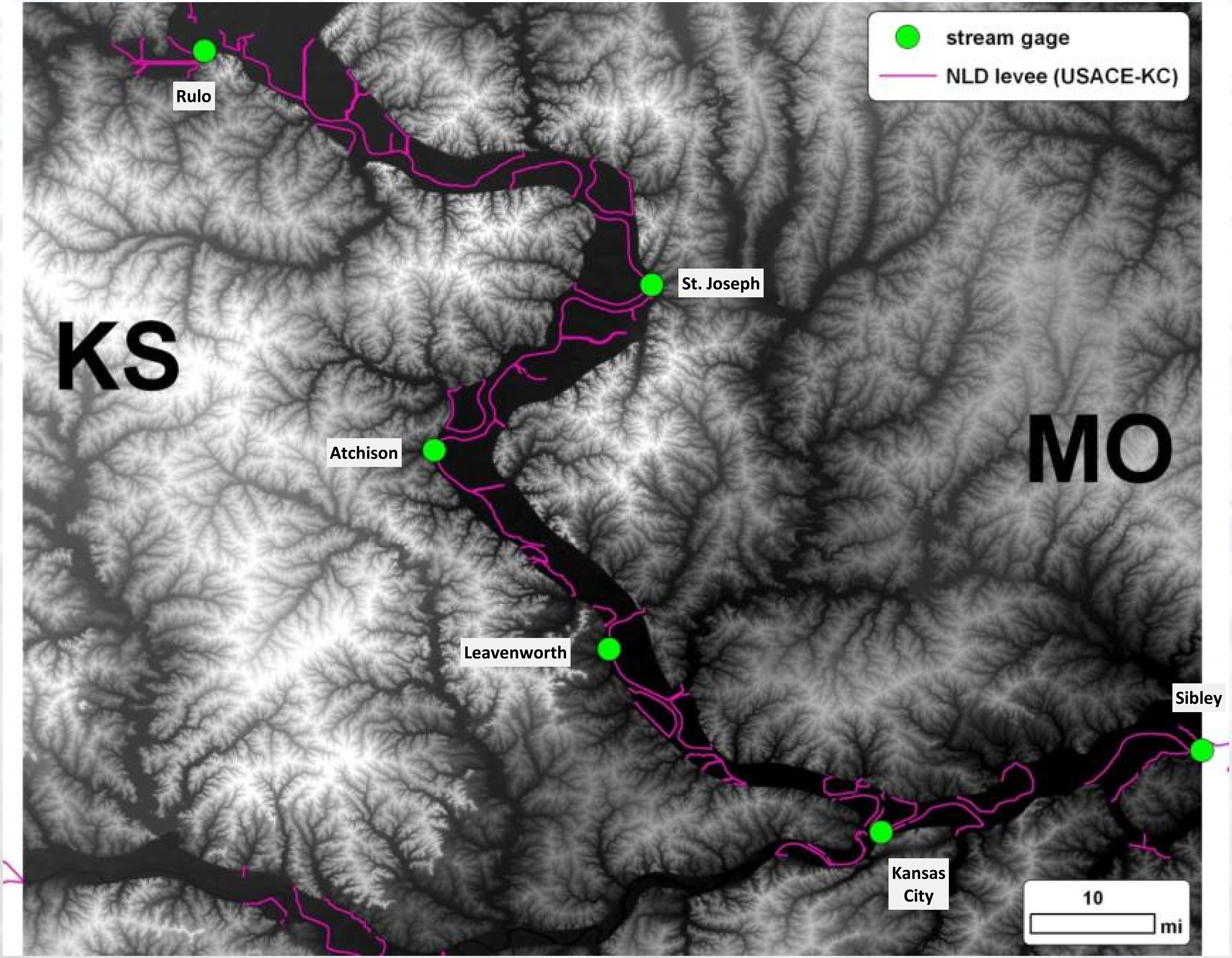


Example 4:

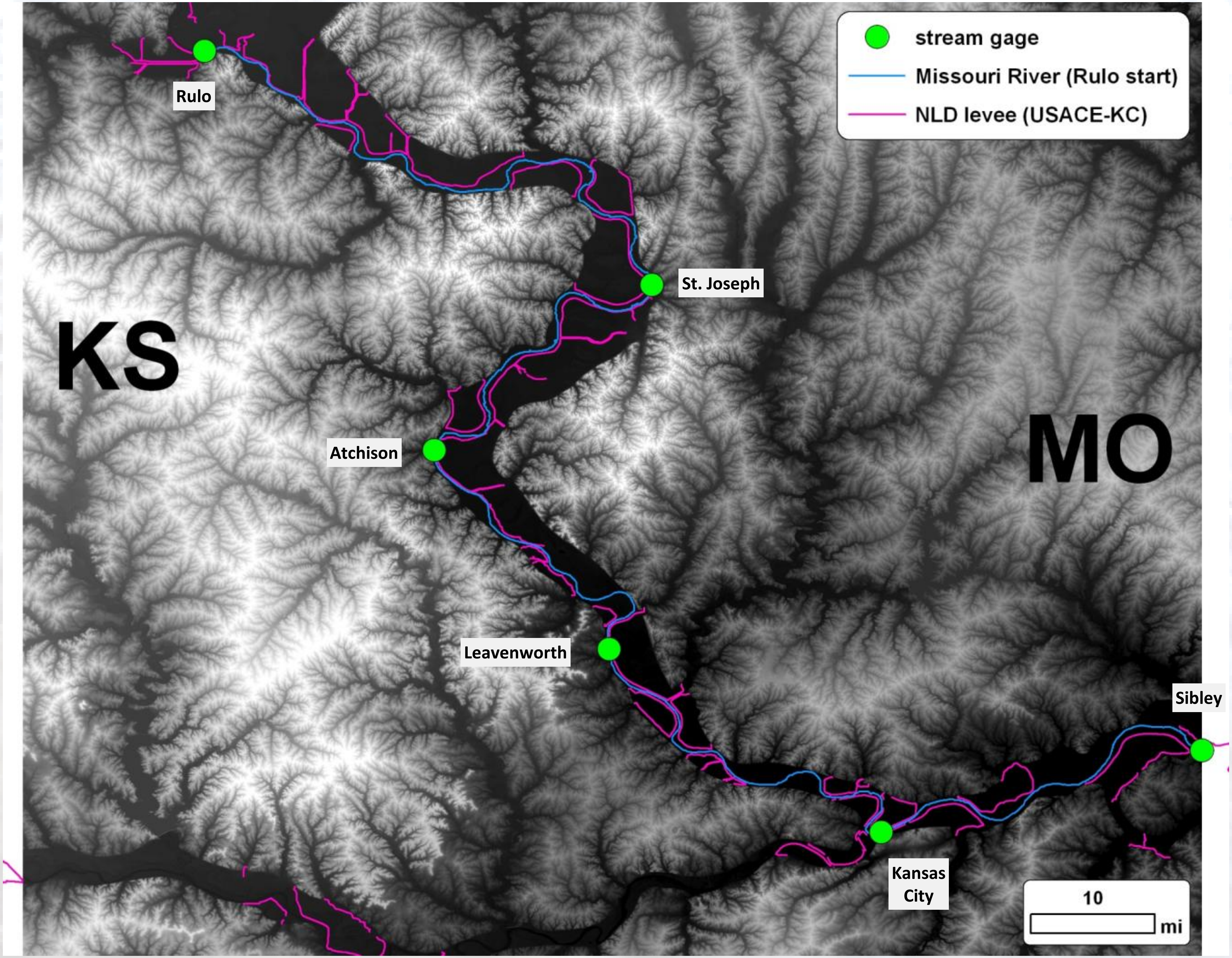
Reconstructing the 1993 Missouri River Flood in Kansas*

KDEM request for 2011 floods

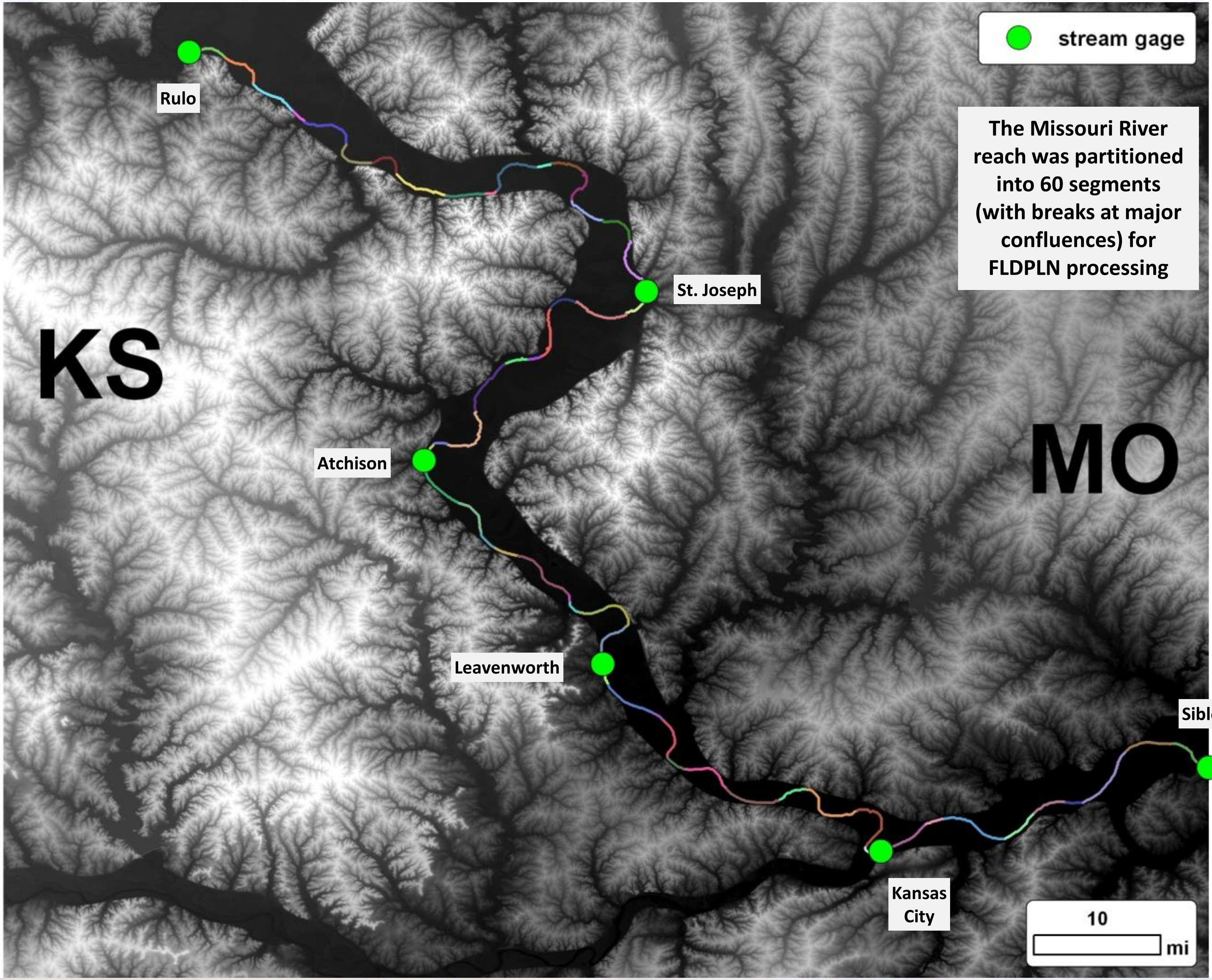

stream gage
Rulo
St. Joseph
KS
Atchison
MO
Leavenworth
Sibley
Kansas
City
10
mi

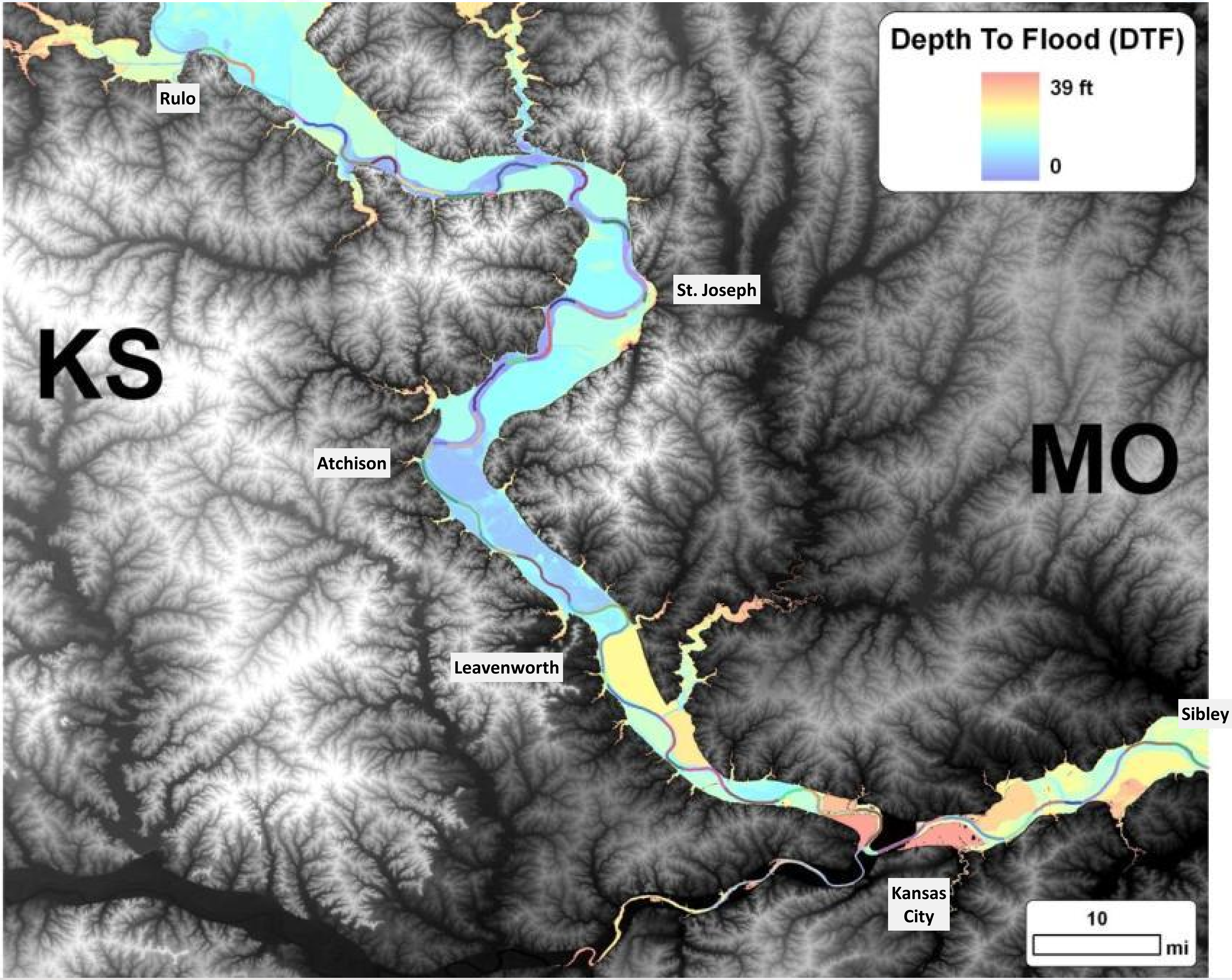


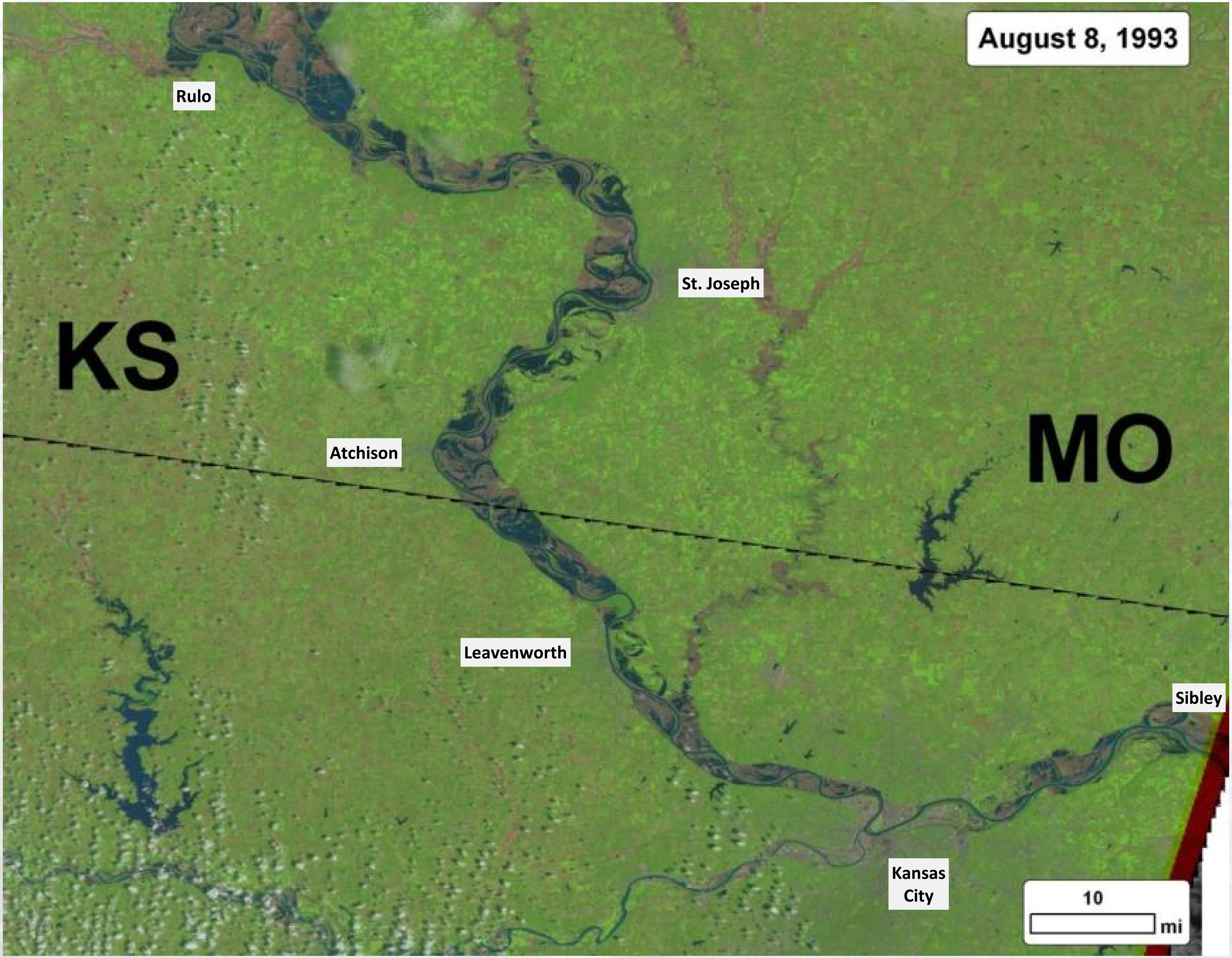
stream gage
NLD levee (USACE-KC)
Rulo
St. Joseph
KS
Atchison
MO
Leavenworth
Sibley
Kansas City
10
mi

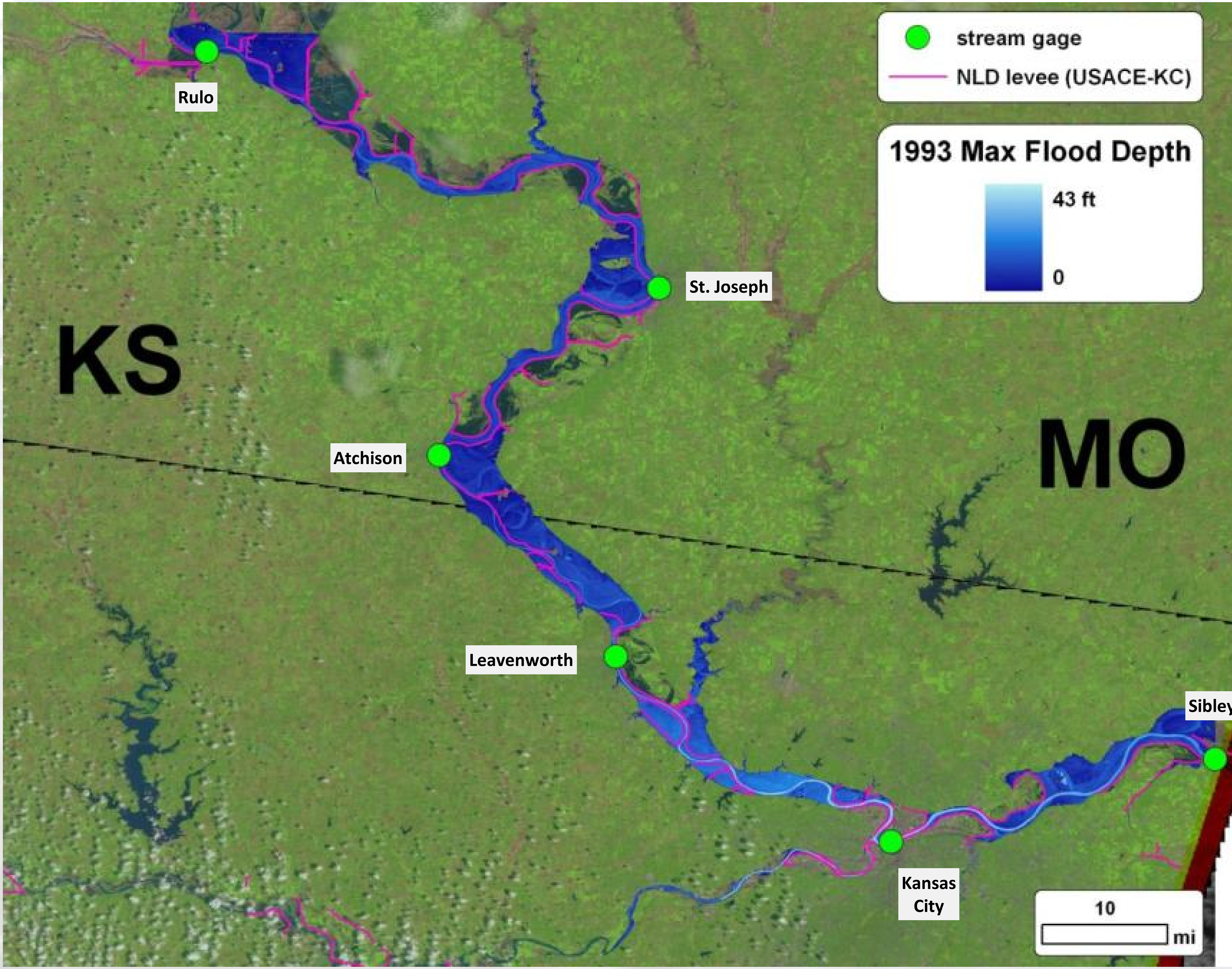


stream gage
Missouri River (Rulo start)
NLD levee (USACE-KC)
Rulo
St. Joseph
KS
Atchison
MO
Leavenworth
Sibley
Kansas City
10
mi


stream gage
The Missouri River reach was partitioned into 60 segments (with breaks at major confluences) for FLDPLN processing
Rulo
St. Joseph
KS
MO
Atchison
Leavenworth
Sibley
Kansas City
10
mi

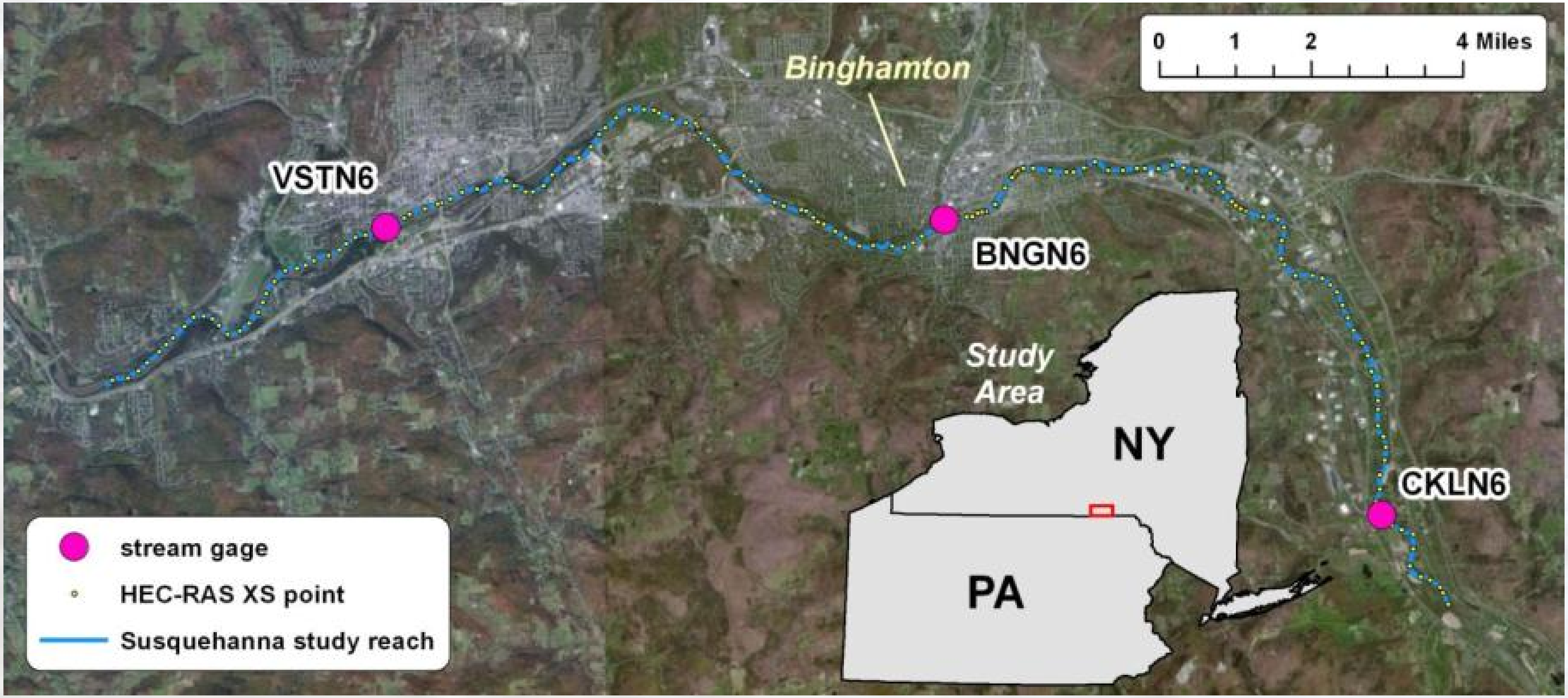

Depth To Flood (DTF)
39 ft
0
Rulo
St. Joseph
KS
Atchison
MO
Leavenworth
Sibley
Kansas
City
10
mi


August 8, 1993
Rulo
St. Joseph
KS
MO
Atchison
Leavenworth
Sibley
Kansas City
10
mi

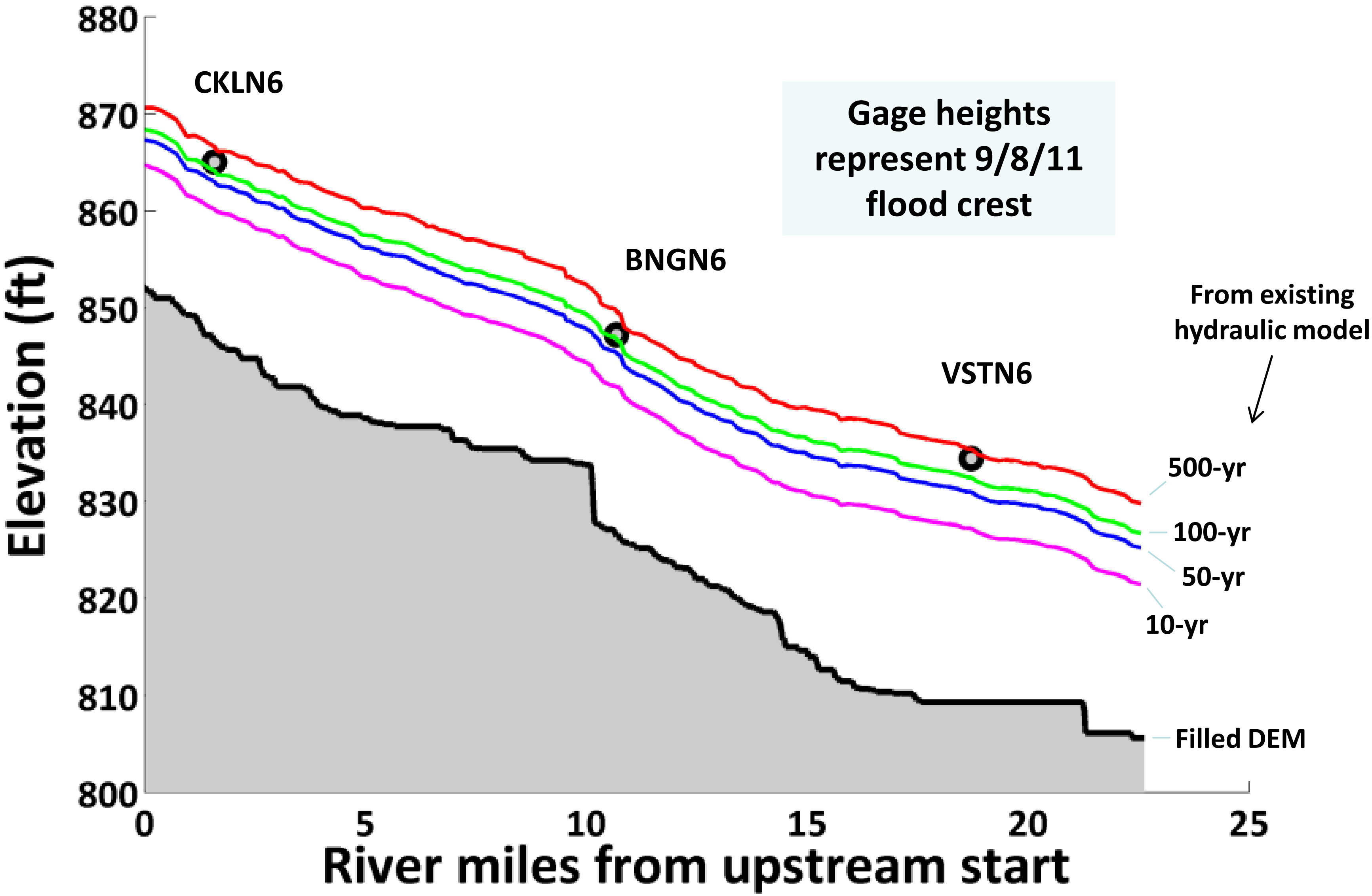


stream gage
NLD levee (USACE-KC)
1993 Max Flood Depth
43 ft
0
Rulo
St. Joseph
KS
MO
Atchison
Leavenworth
Sibley
Kansas City
10
mi

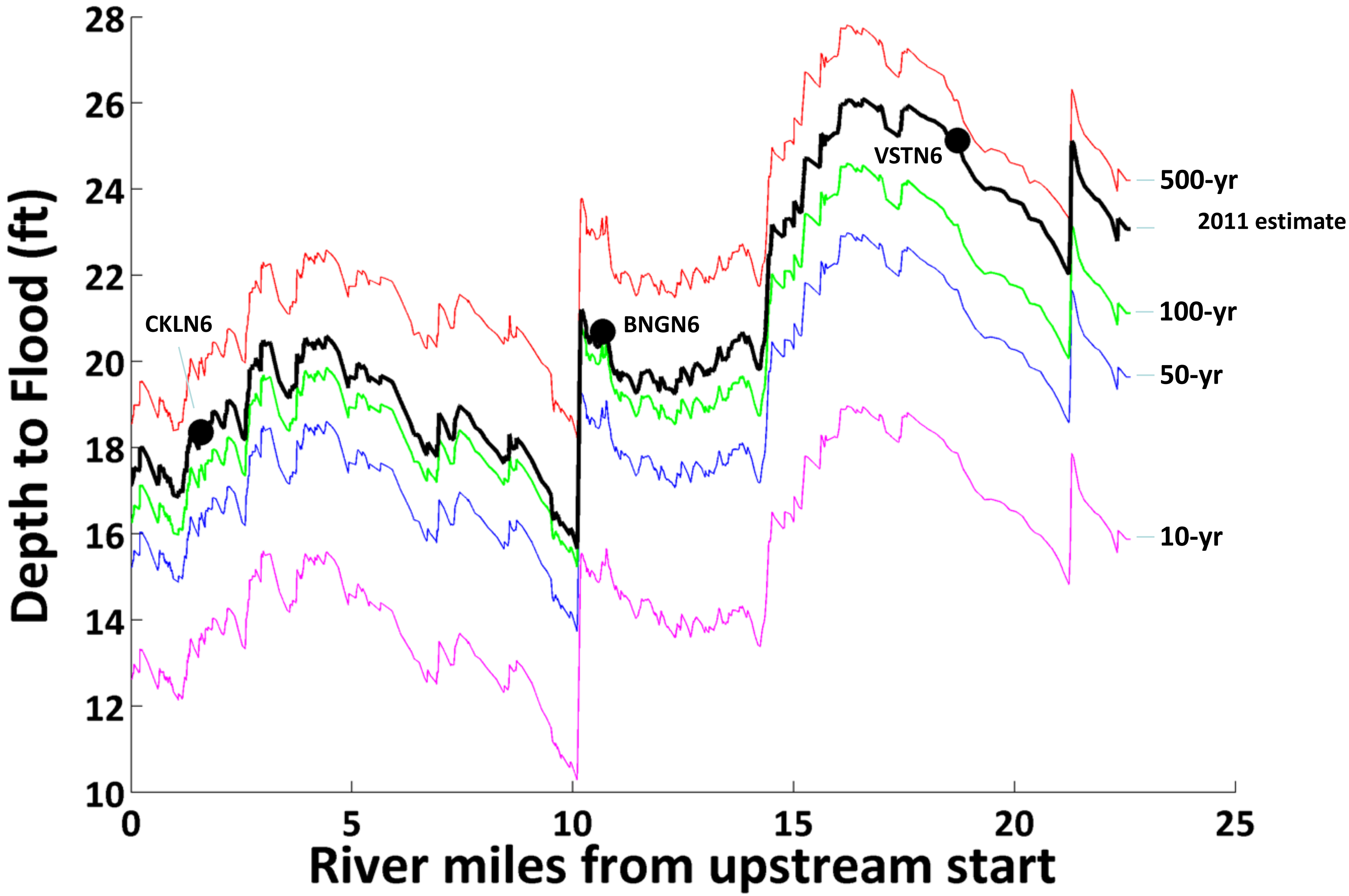
Example 5: Susquehanna River

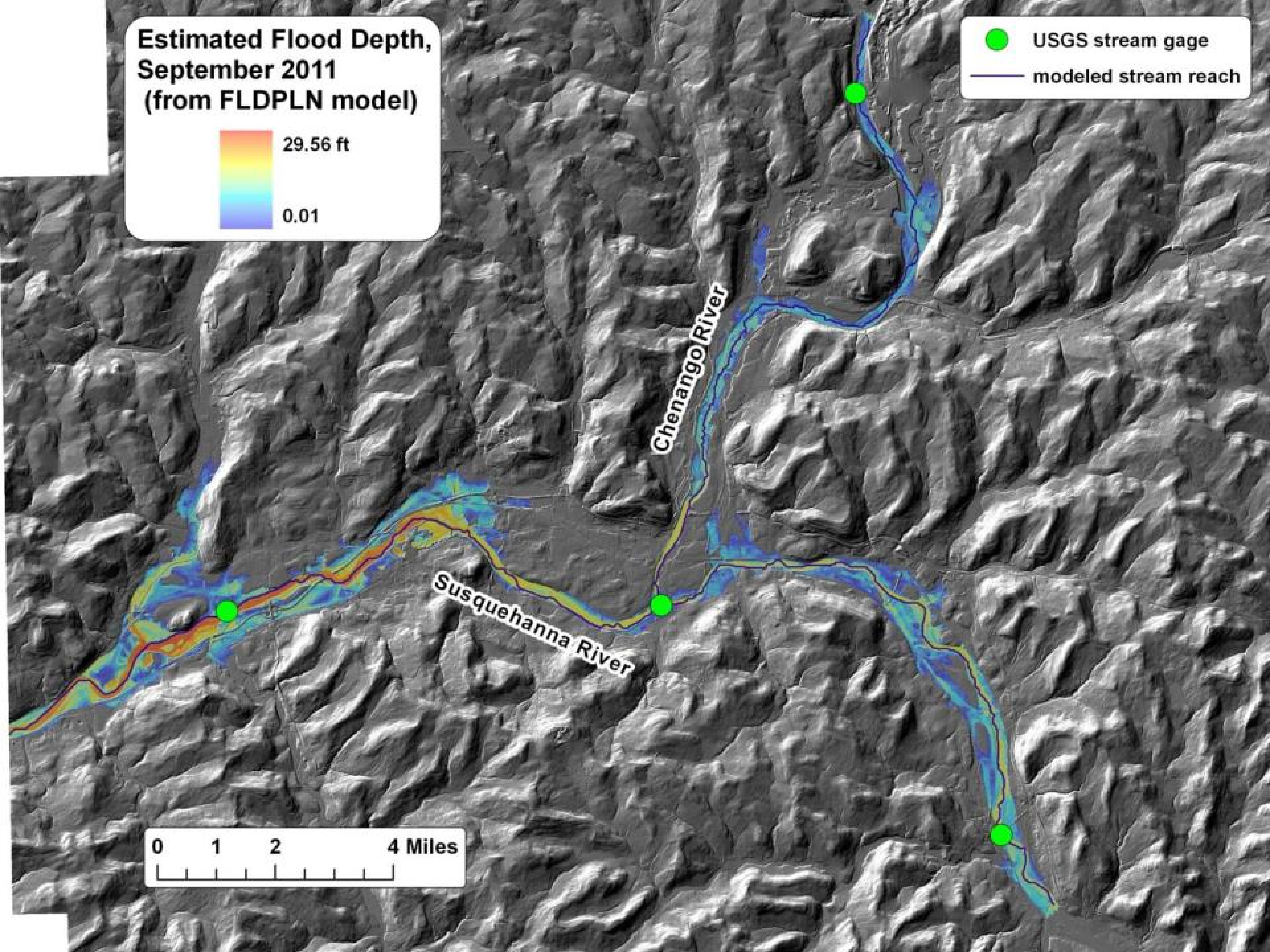


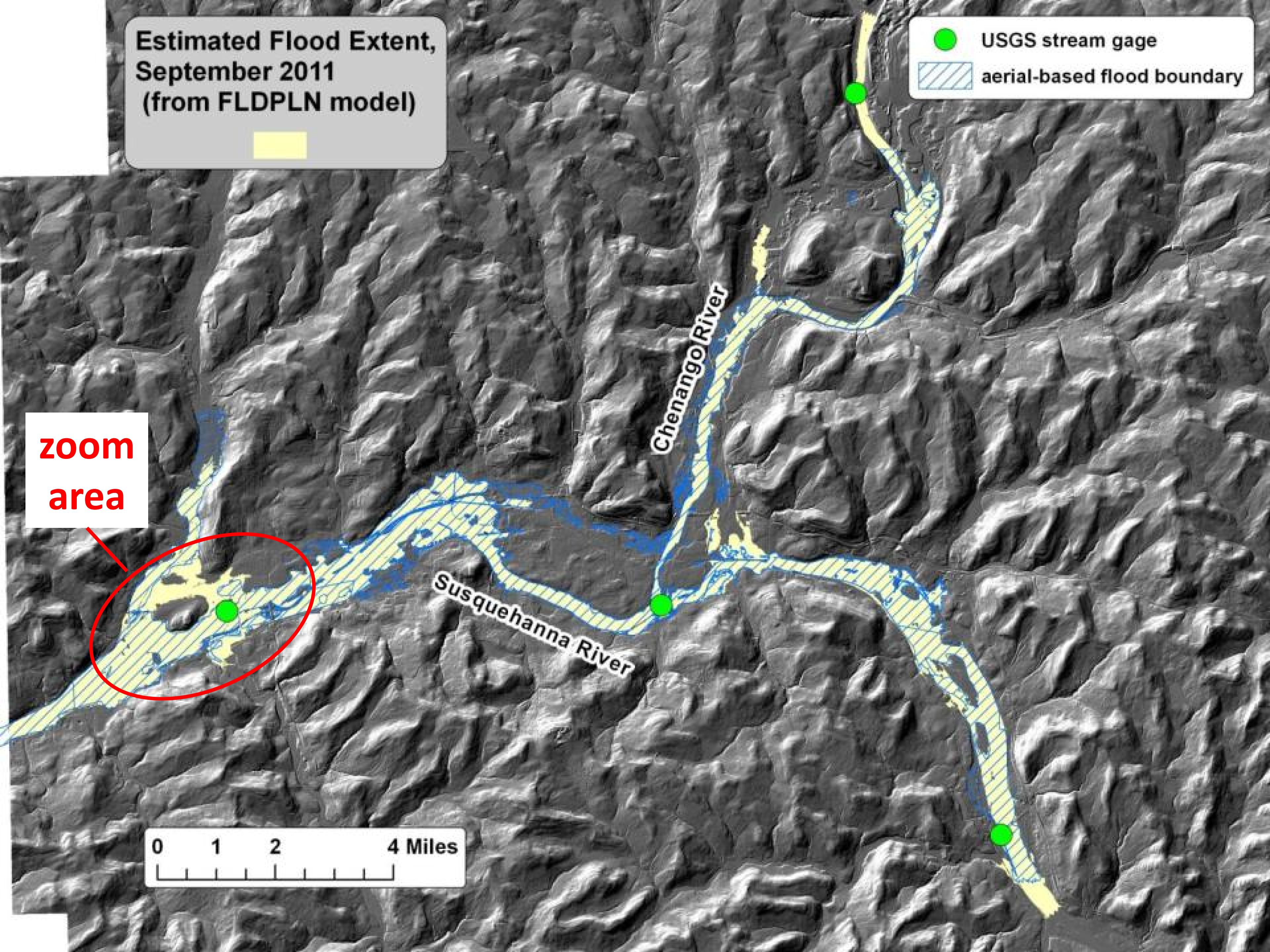
Susquehanna River Water Surface Elevations



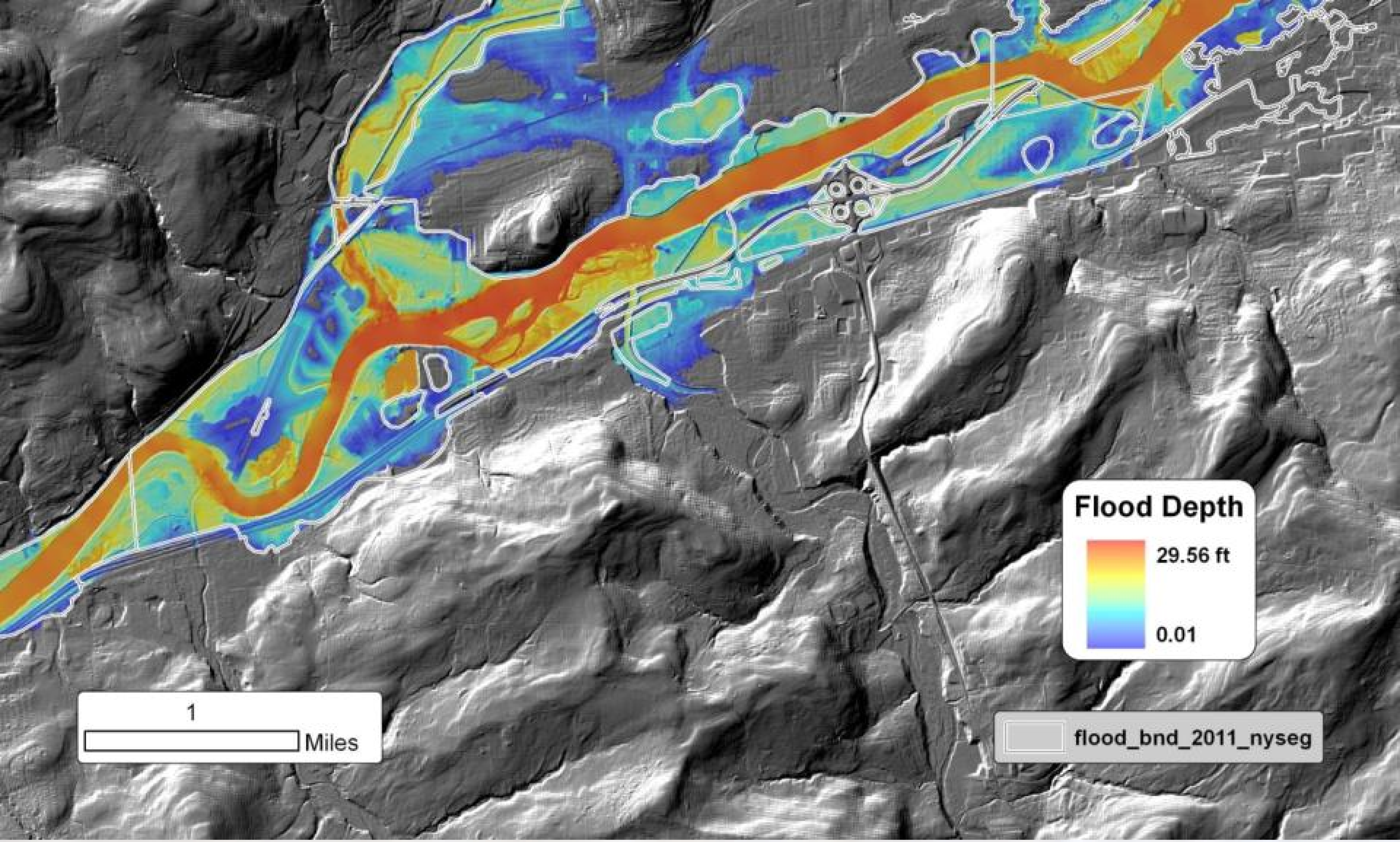
Susquehanna River Pixel-level DTF Values



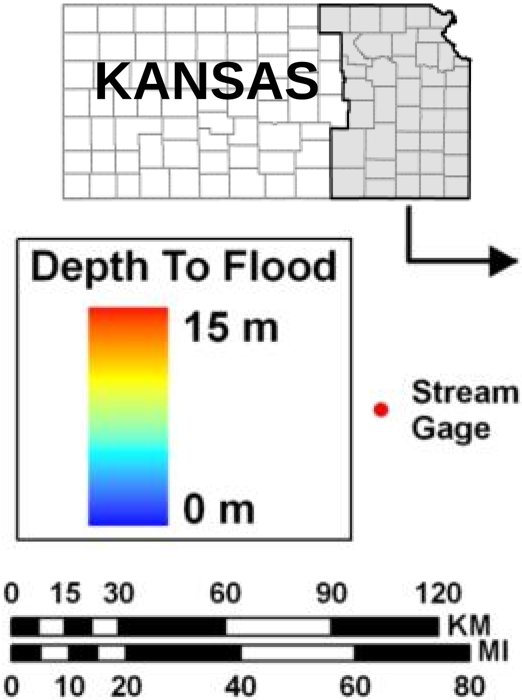

Estimated Flood Depth,
September 2011
(from FLDPLN model)
29.56 ft
0.01
USGS stream gage
modeled stream reach
Chenango River
Susquehanna River
0
1
2
4 Miles



Estimated Flood Extent, September 2011 (from FLDPLN model)
USGS stream gage
aerial-based flood boundary
zoom area
Chenango River
Susquehanna River
0
1
2
4 Miles

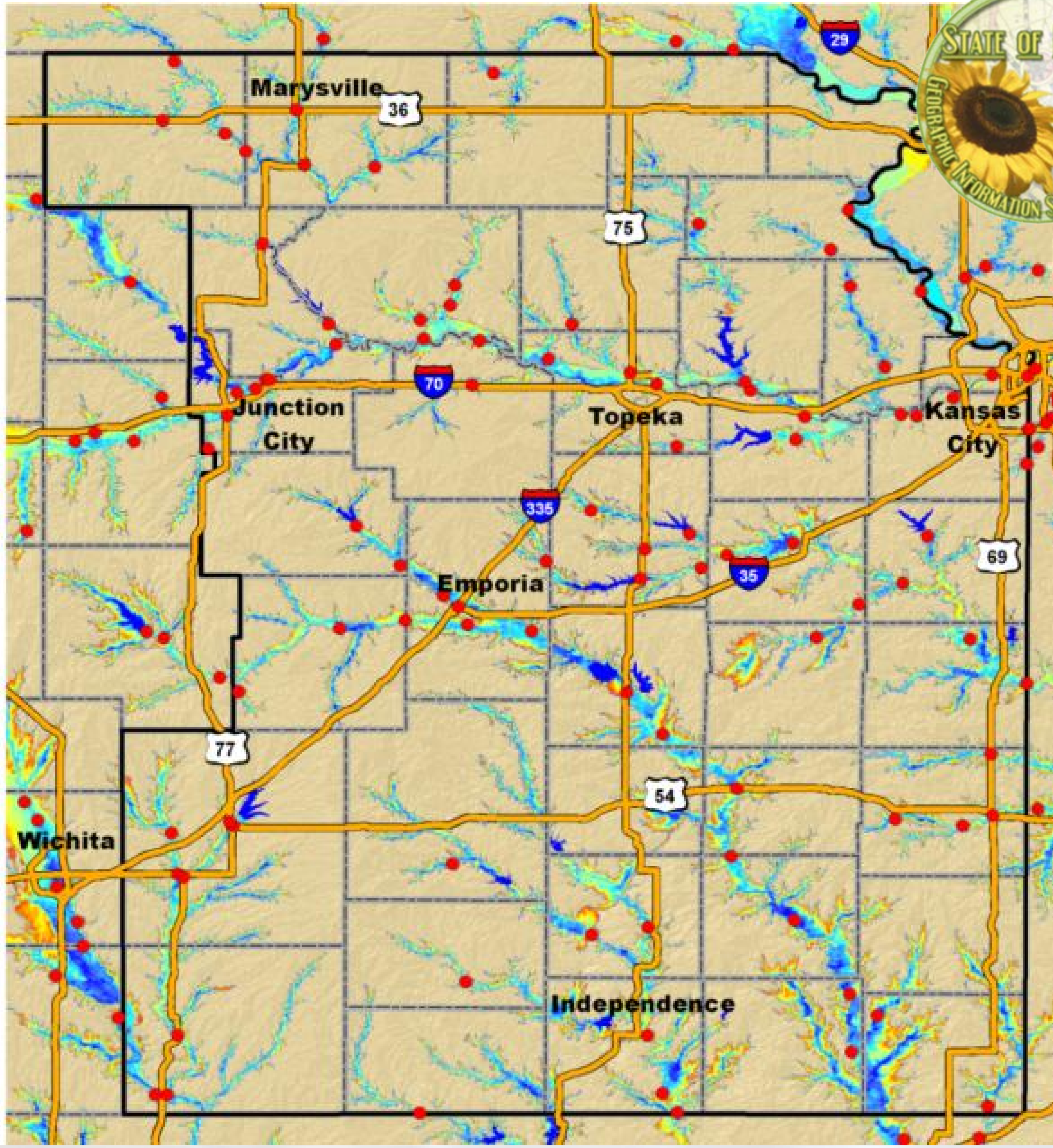


Flood Depth Grid estimate for September 2011 flood event (FLDPLN SLIE)

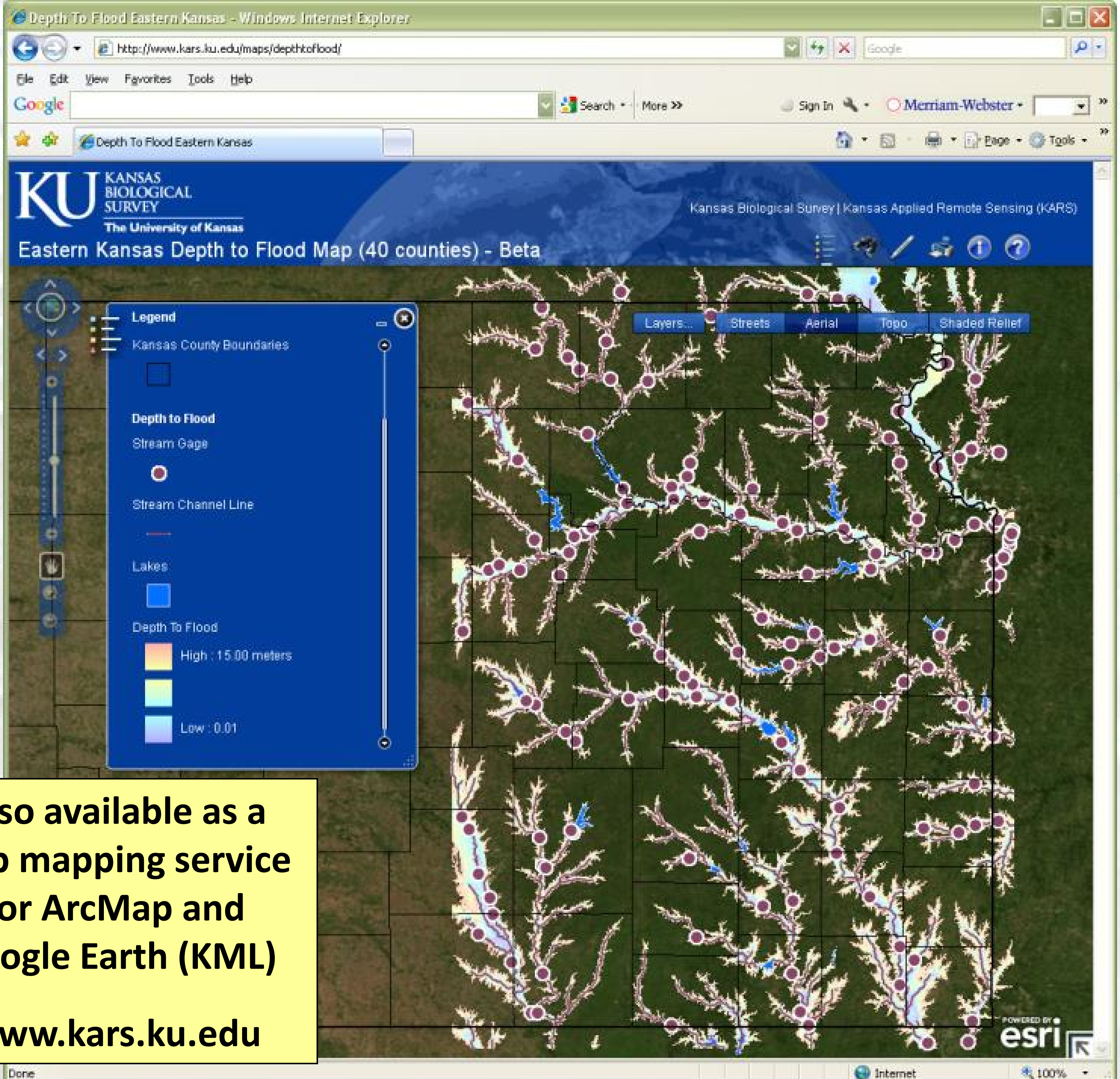


This floodplain database (called a Segmented Library of Inundation Extents, or SLIE) was developed for 339 stream segments in eastern Kansas.

Using river stage information from gages and observers, the SLIE is used to produce current and predicted flood extents during severe flooding to improve situational awareness for disaster response personnel.



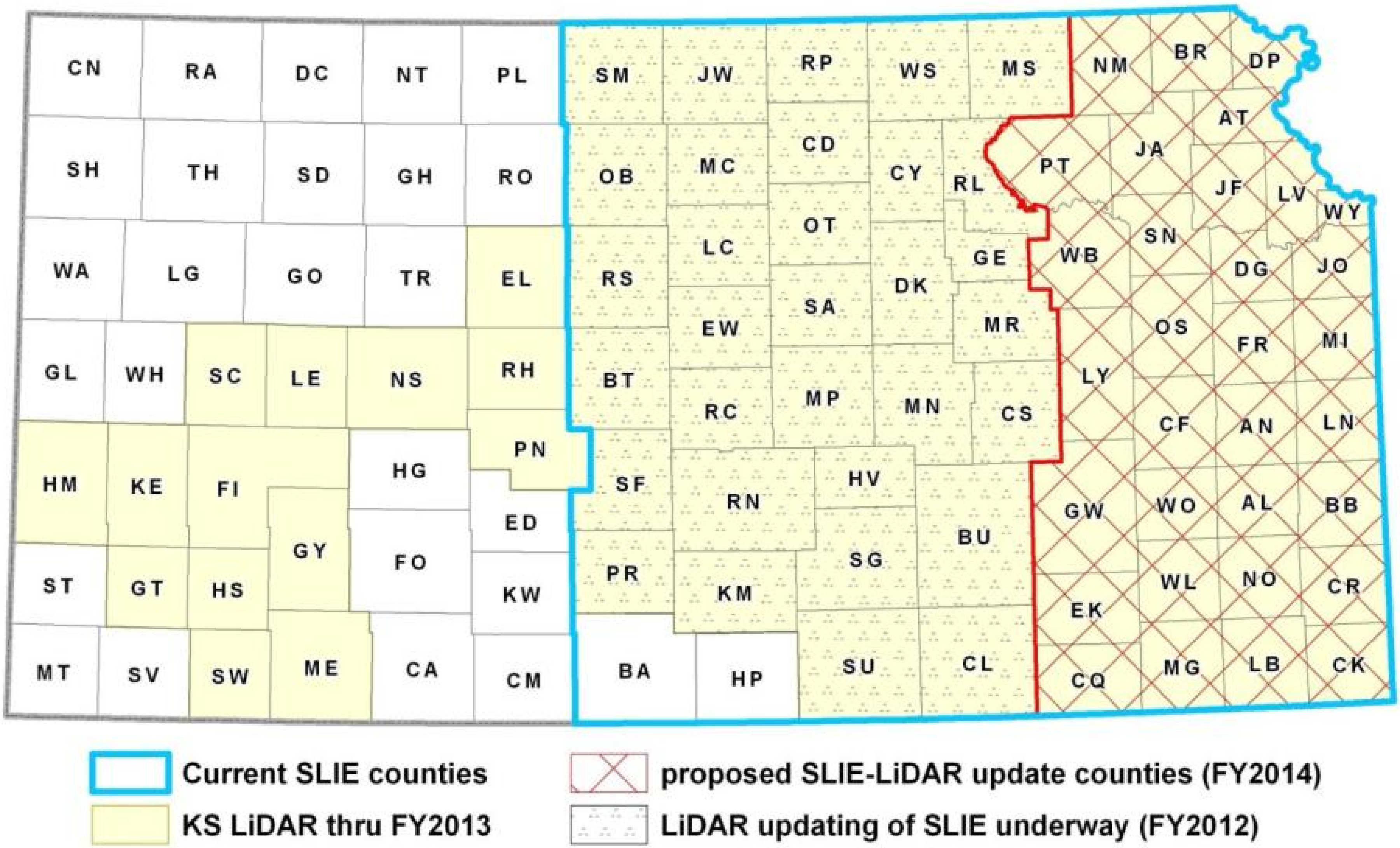
Website: ***http://www.kars.ku.edu/geodata/maps/depth-flood-eastern-kansas/***



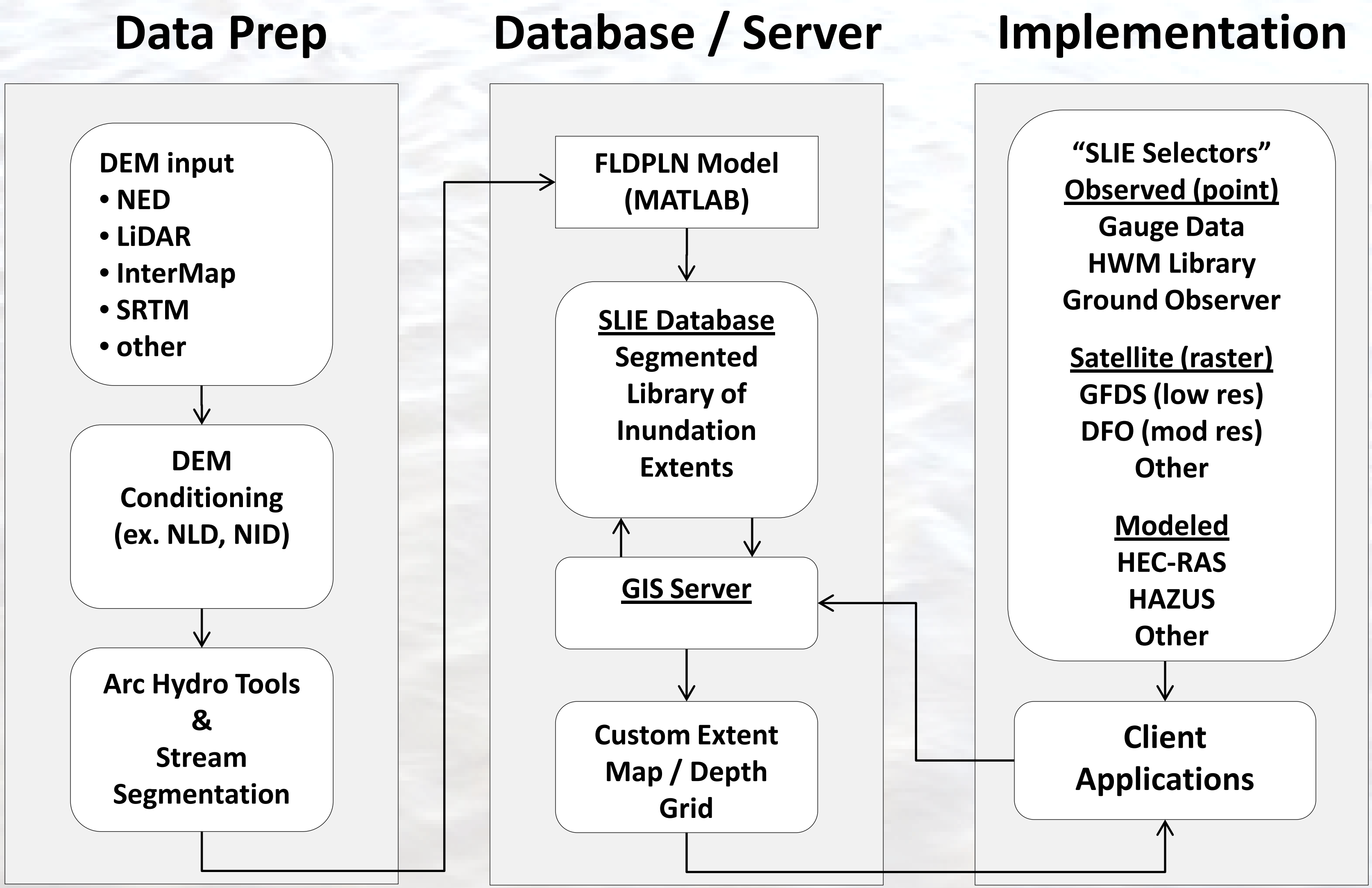
Also available as a web mapping service for ArcMap and Google Earth (KML)

www.kars.ku.edu

Kansas SLIE: Expansion and LiDAR update

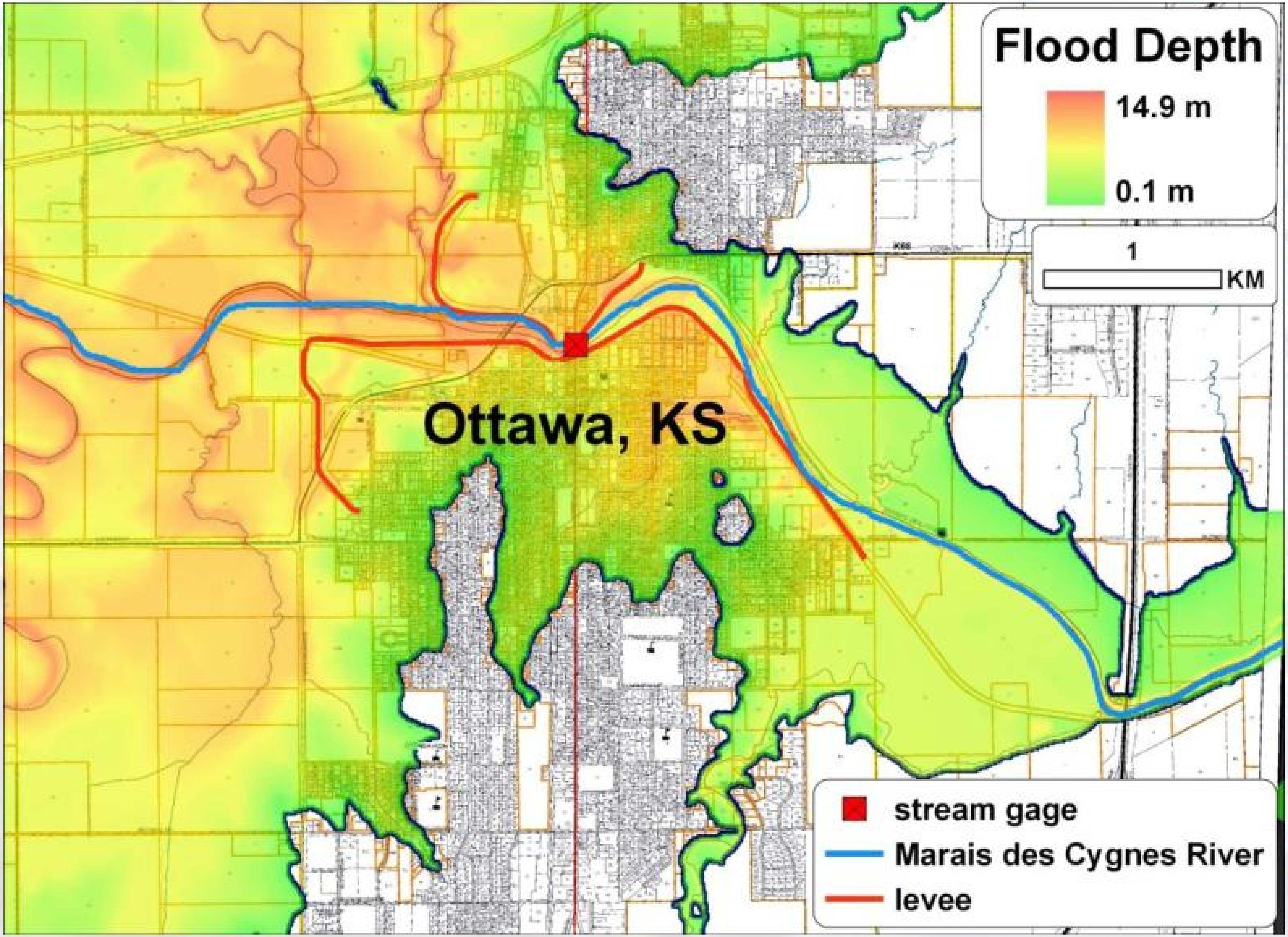


Conceptual Framework

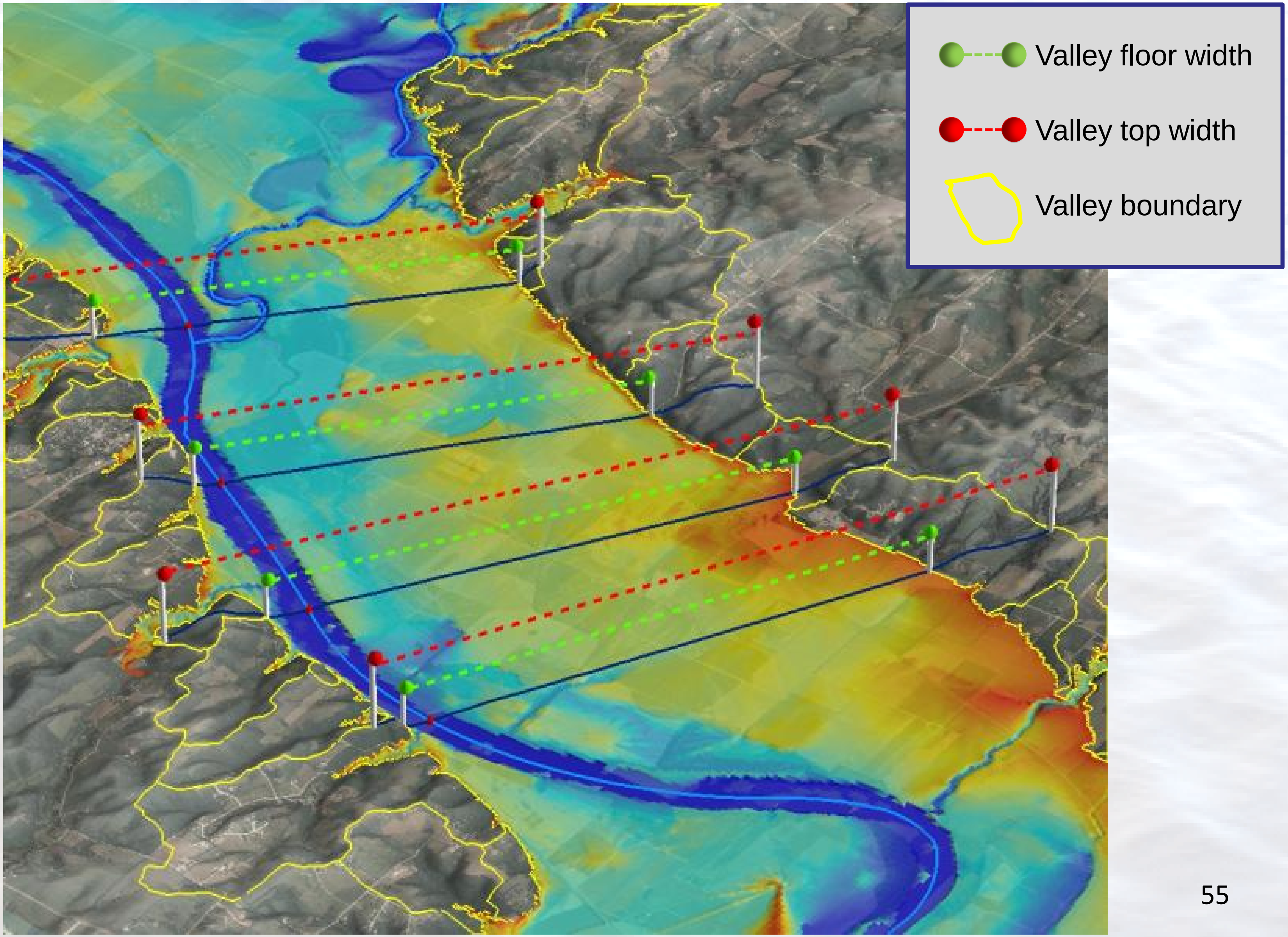


Other Applications for the FLDPLN Model

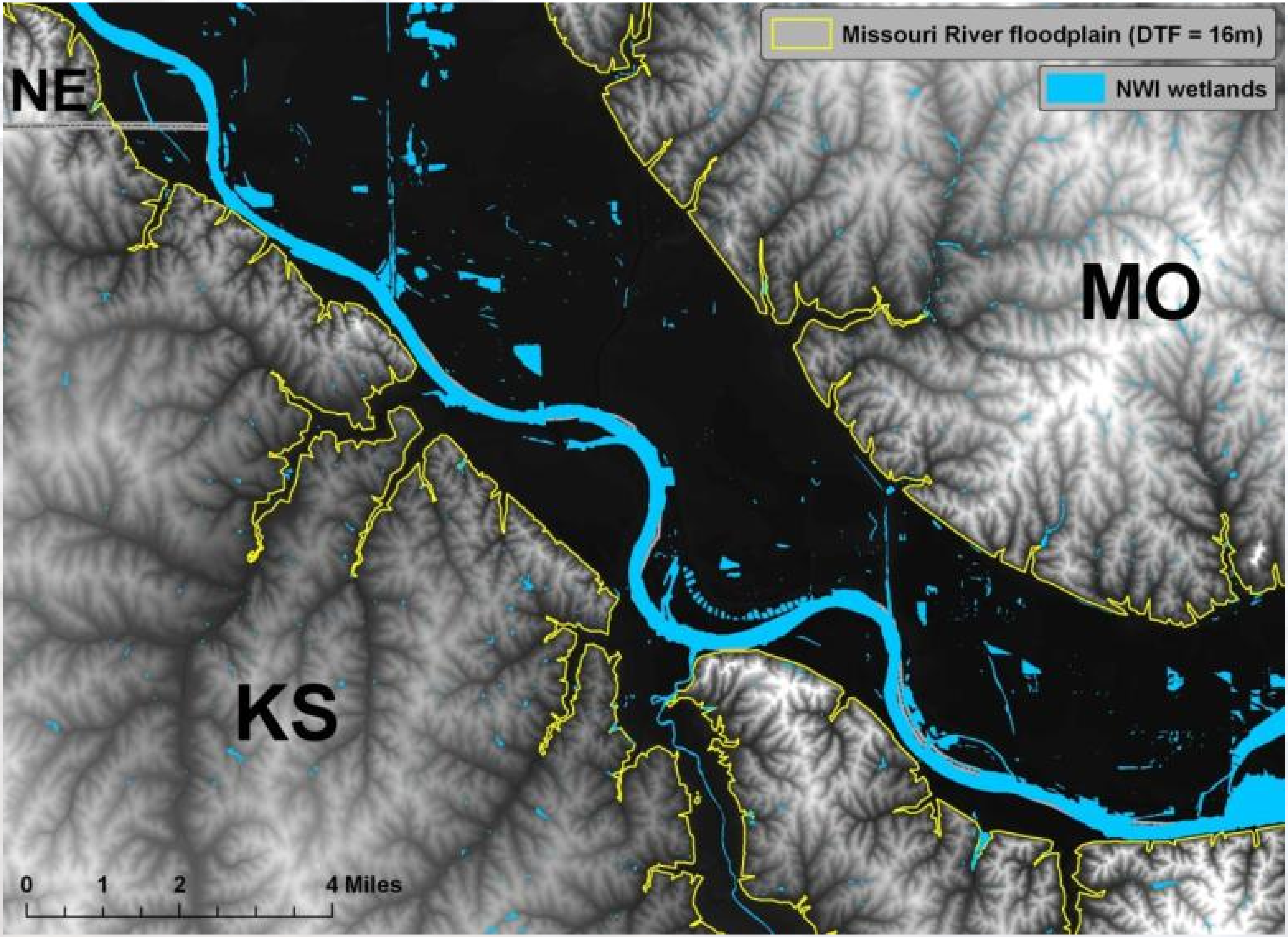
Flood scenario modeling for training exercises –
HWM targeting and estimation of flood depth grid



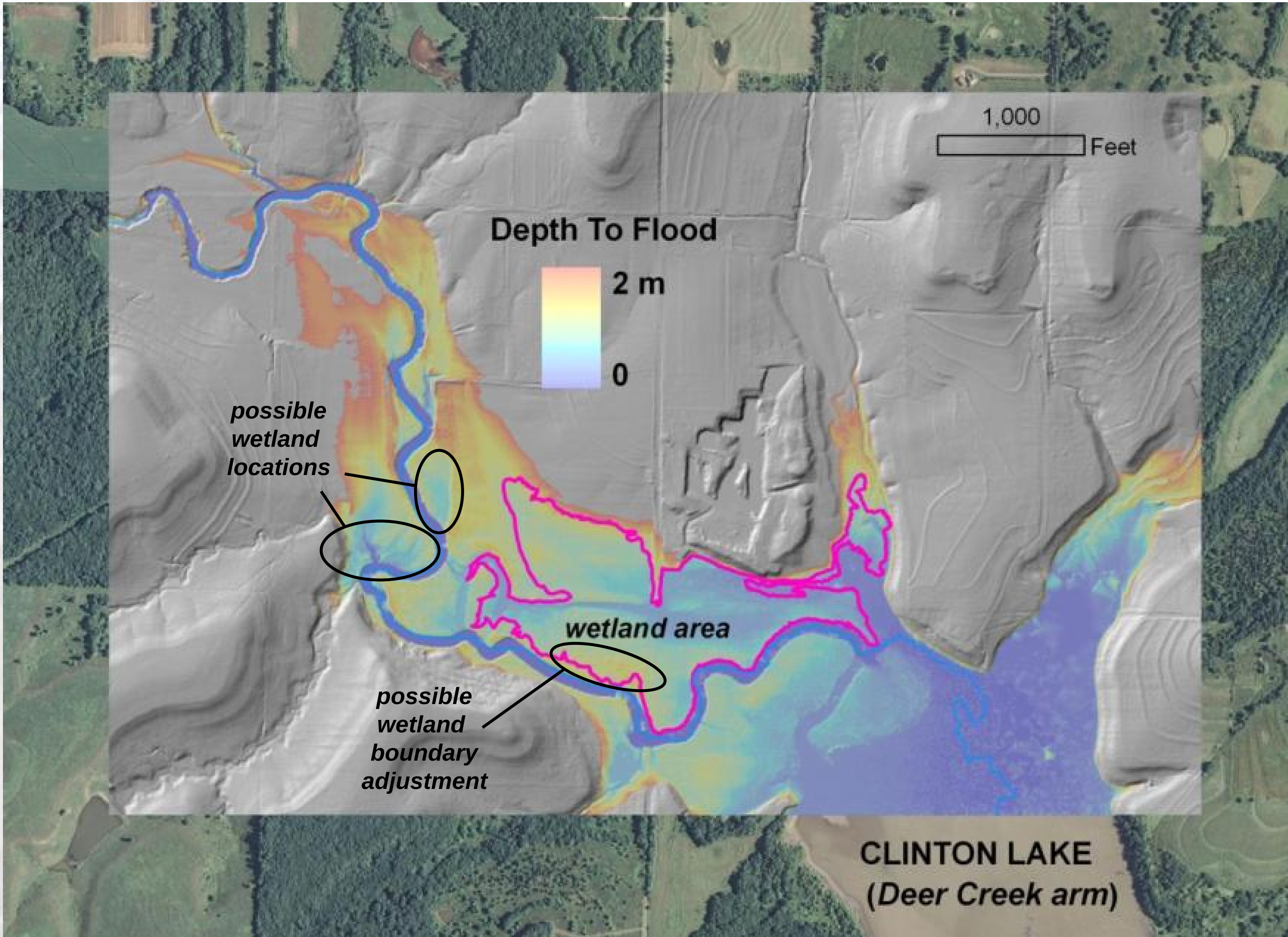
River typing and morphology studies – valley identification and floor width estimation

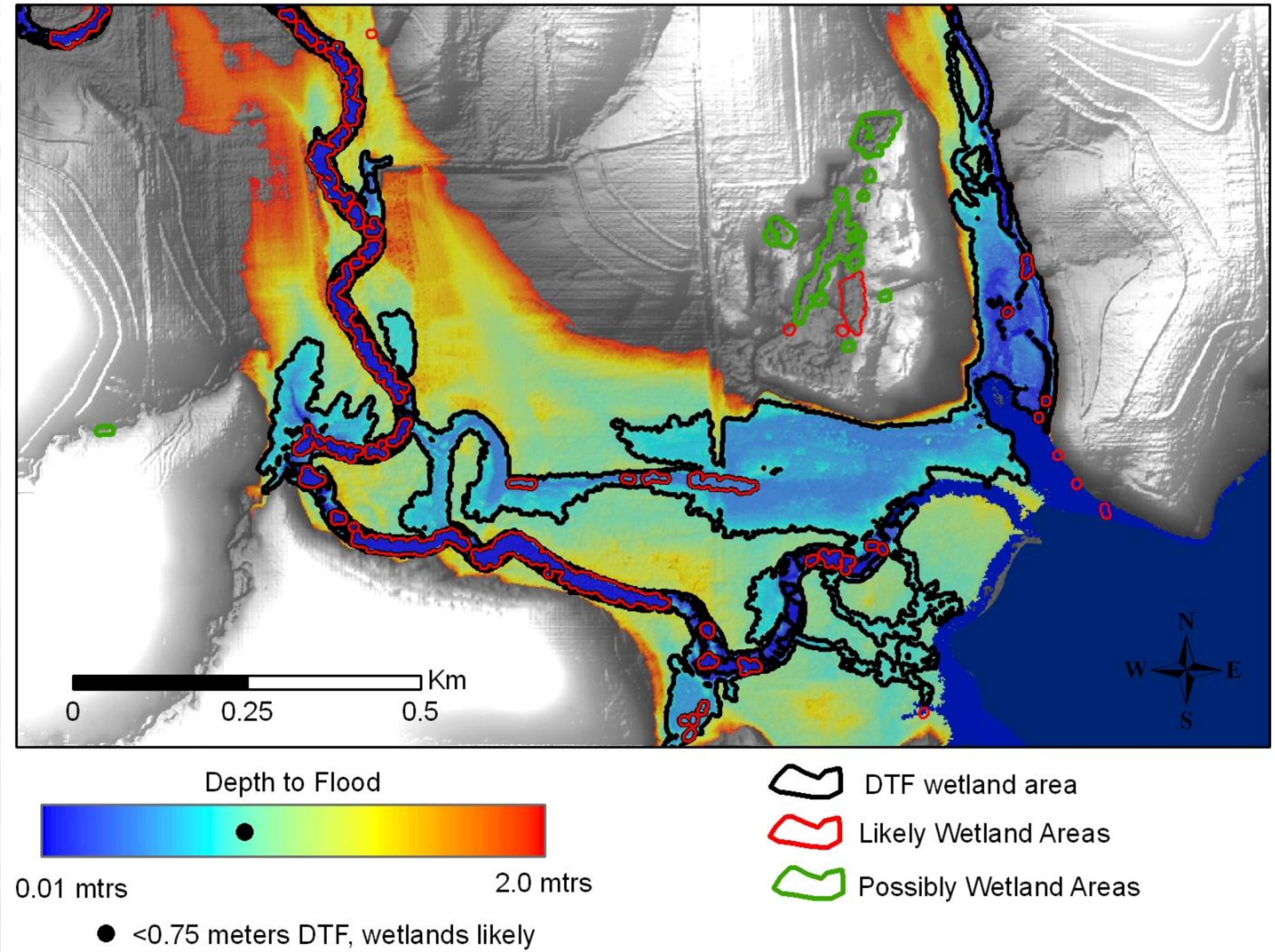


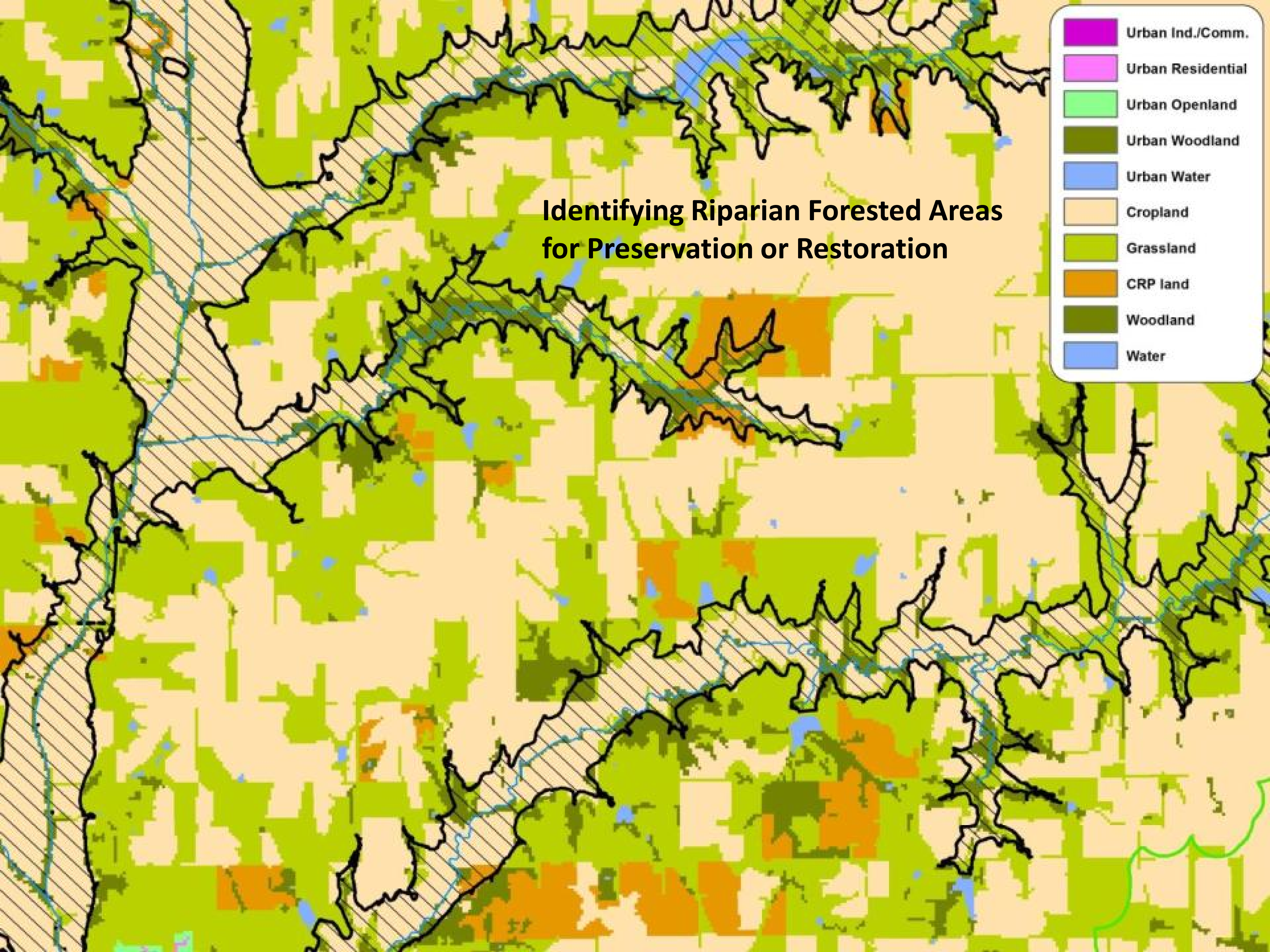
River valley boundary delineation – masking for identification of floodplain wetlands



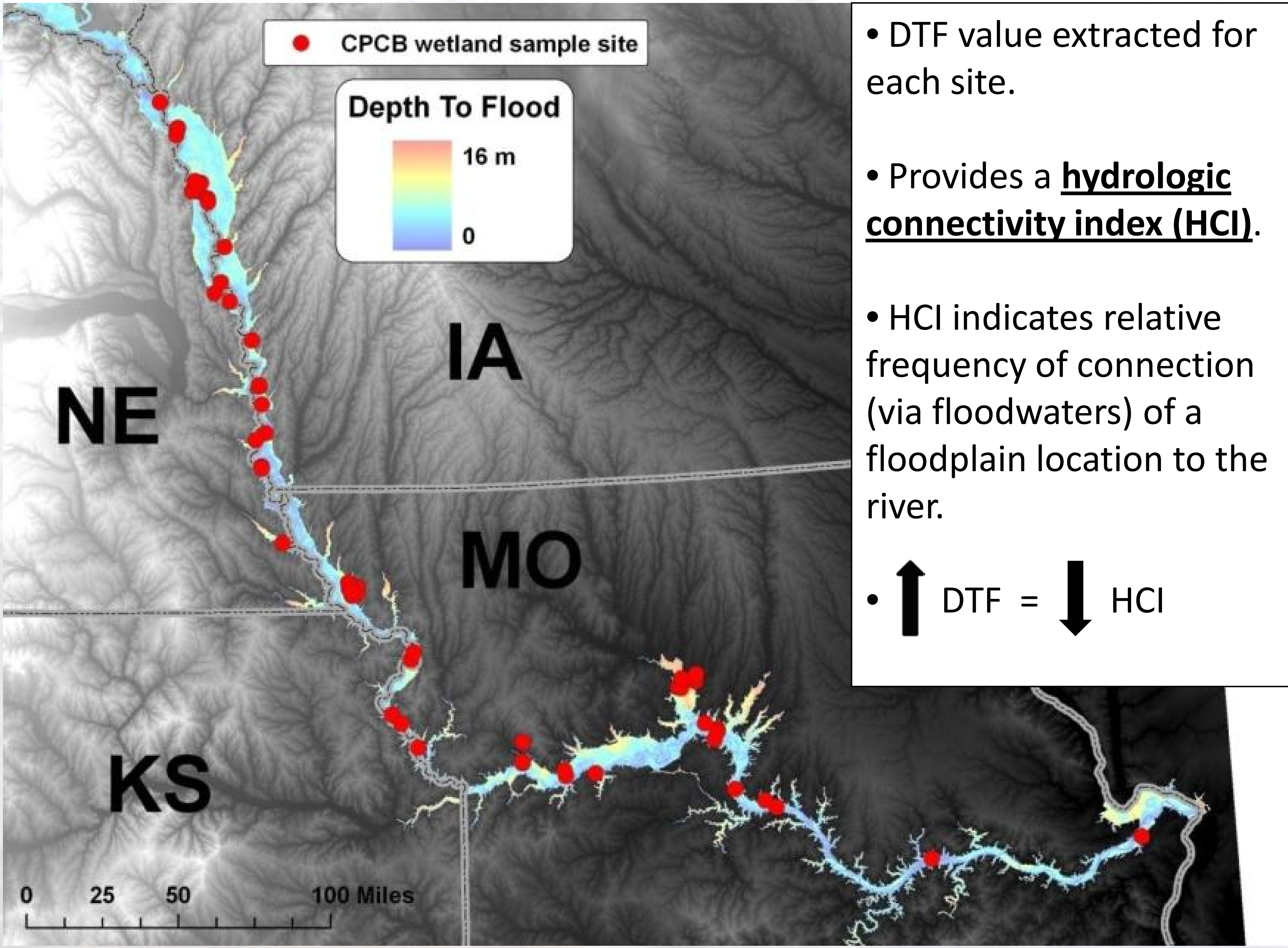
Identifying potential wetland locations & wetland boundary refinement




Km
0
0.25
0.5
N
W
E
S
Depth to Flood
0.01 mtrs
2.0 mtrs
<0.75 meters DTF, wetlands likely
DTF wetland area
Likely Wetland Areas
Possibly Wetland Areas

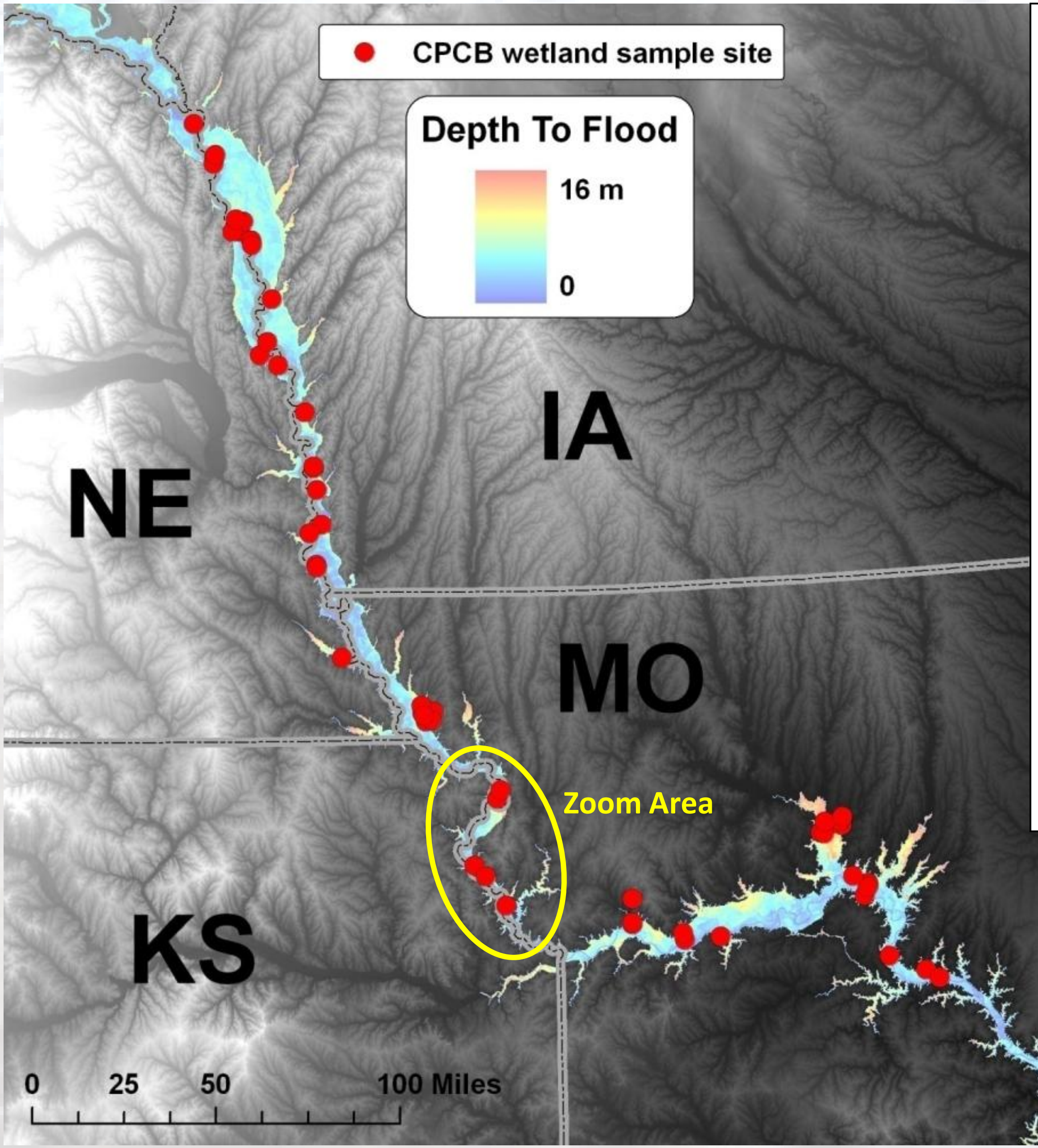

Identifying Riparian Forested Areas for Preservation or Restoration
Urban Ind./Comm.
Urban Residential
Urban Openland
Urban Woodland
Urban Water
Cropland
Grassland
CRP land
Woodland
Water

Assessing Wetland Hydrologic Connectivity



- DTF value extracted for each site.
- Provides a **hydrologic connectivity index (HCI)**.
- HCI indicates relative frequency of connection (via floodwaters) of a floodplain location to the river.
- ↑ DTF = ↓ HCI

Assessing Wetland Hydrologic Connectivity



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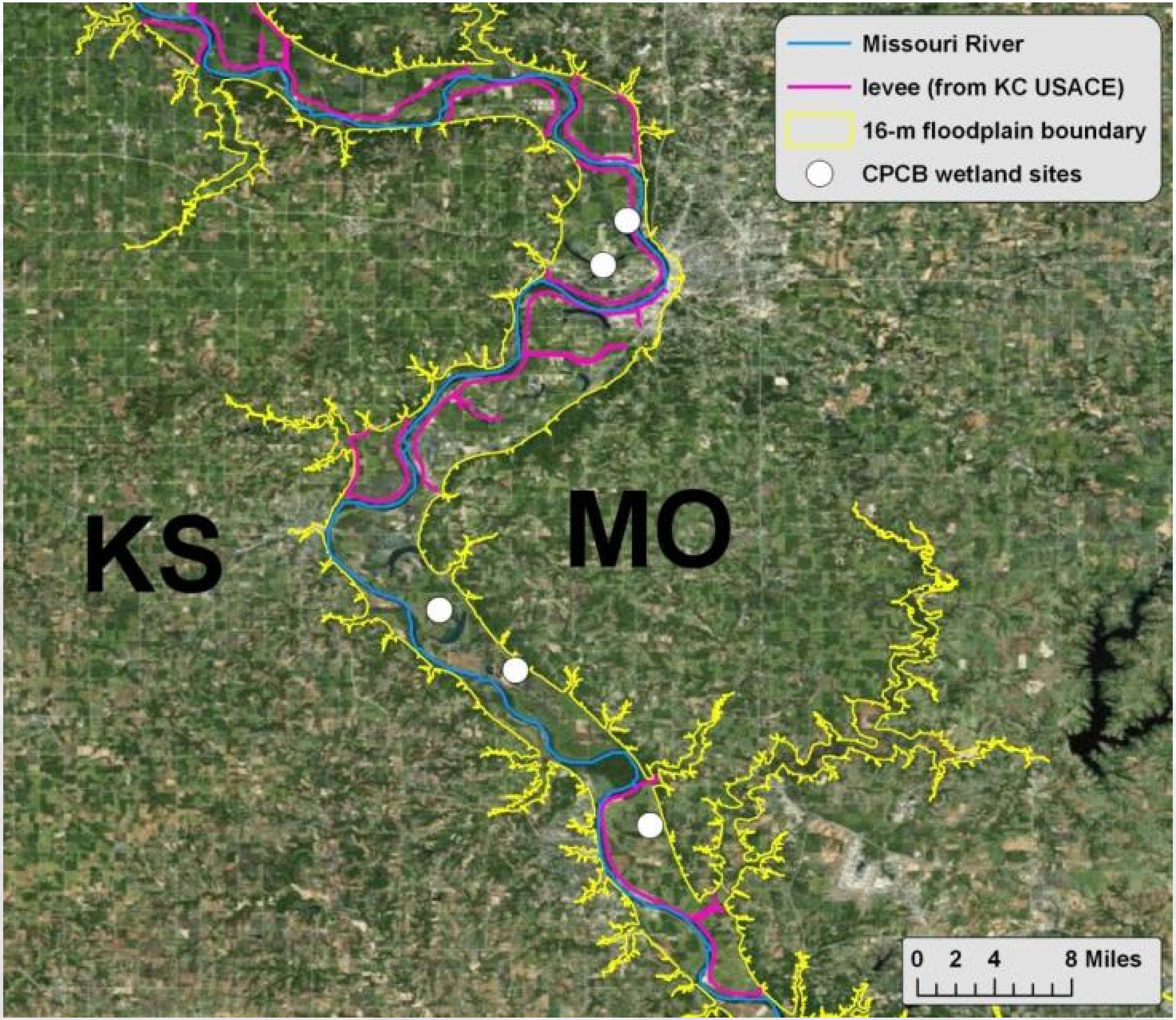
Levee Effects on Wetland Hydrologic Connectivity

• XYZ levee data obtained from KC USACE.

• Acquired as part of the National Levee Database (NLD) effort.

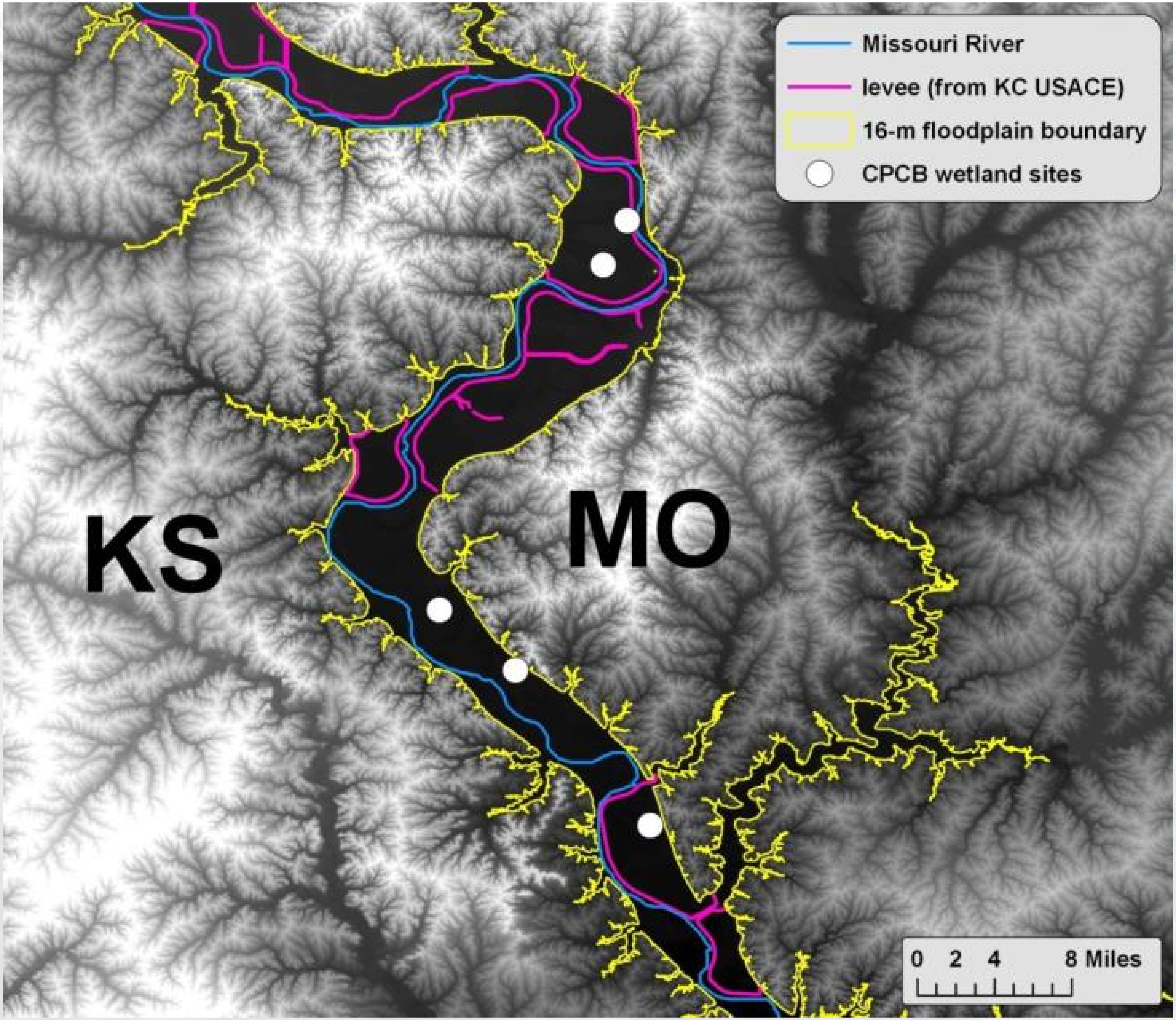
• **Some levees are absent***

**Many of these are included in the latest version of the NLD.*



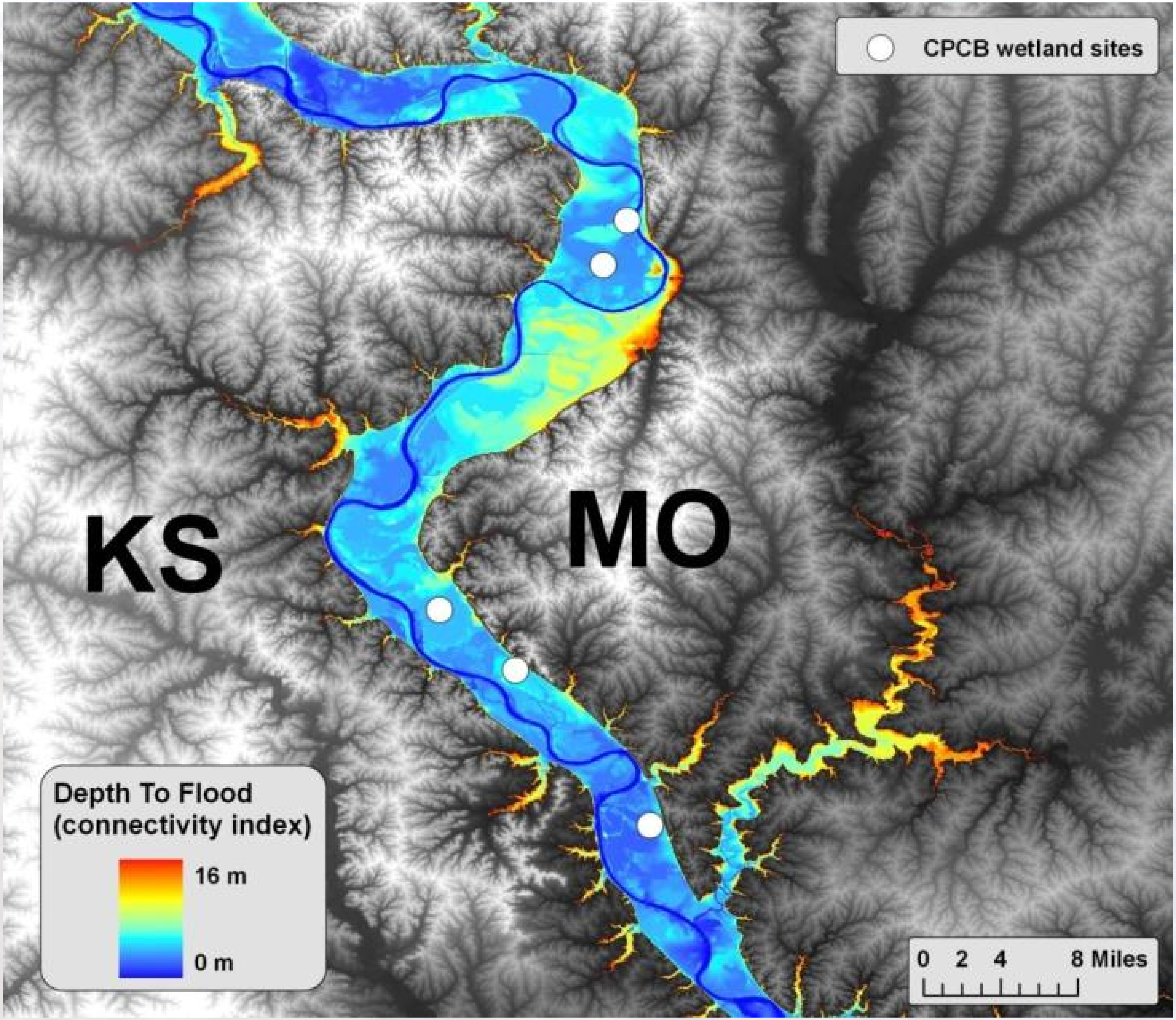
Levee Effects on Wetland Hydrologic Connectivity

30-m DEM data backdrop.



Without levee data

- FLDPLN
- **No levee data.**
- ⬆DTF = ⬇HCI

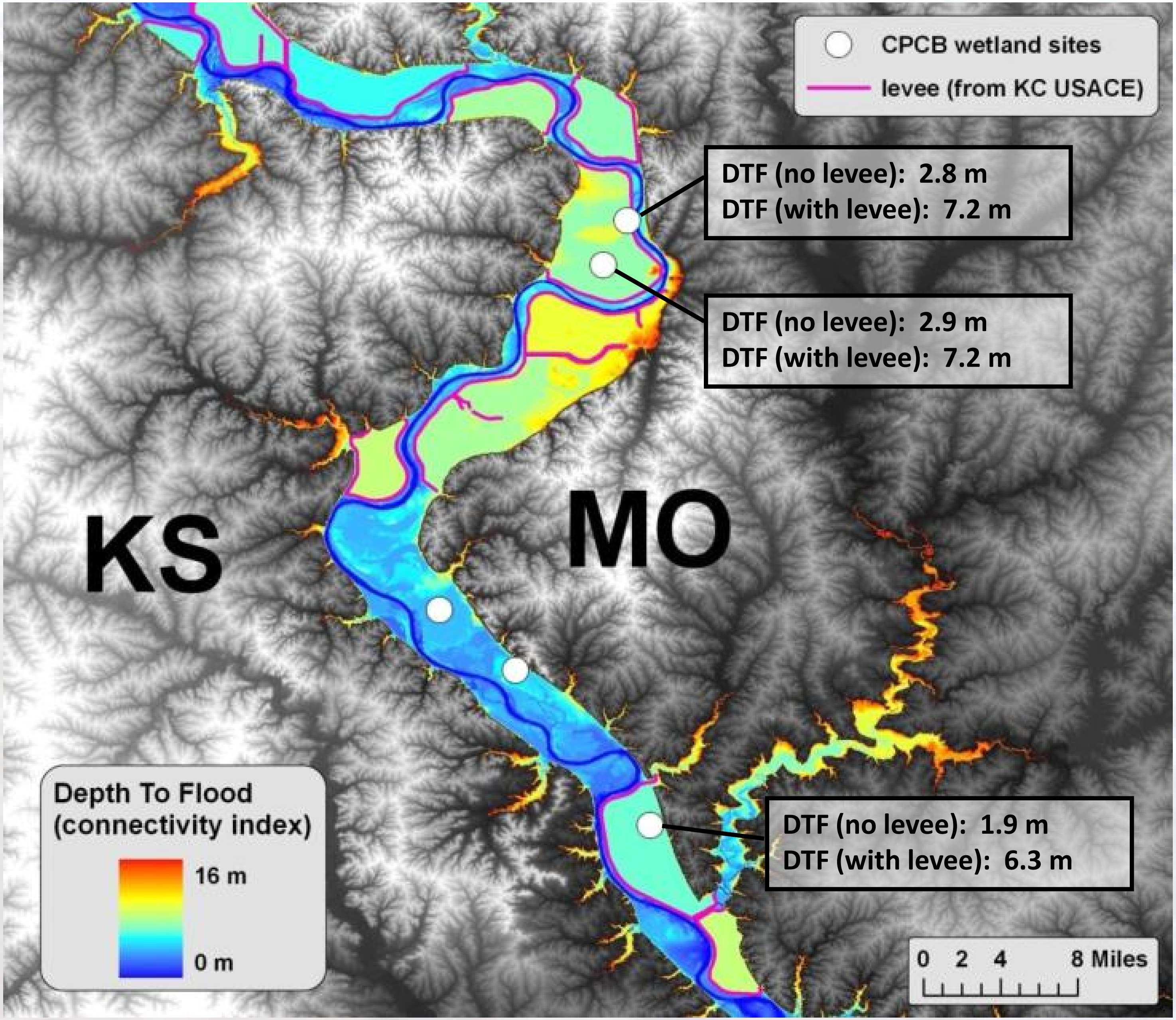


With levee data

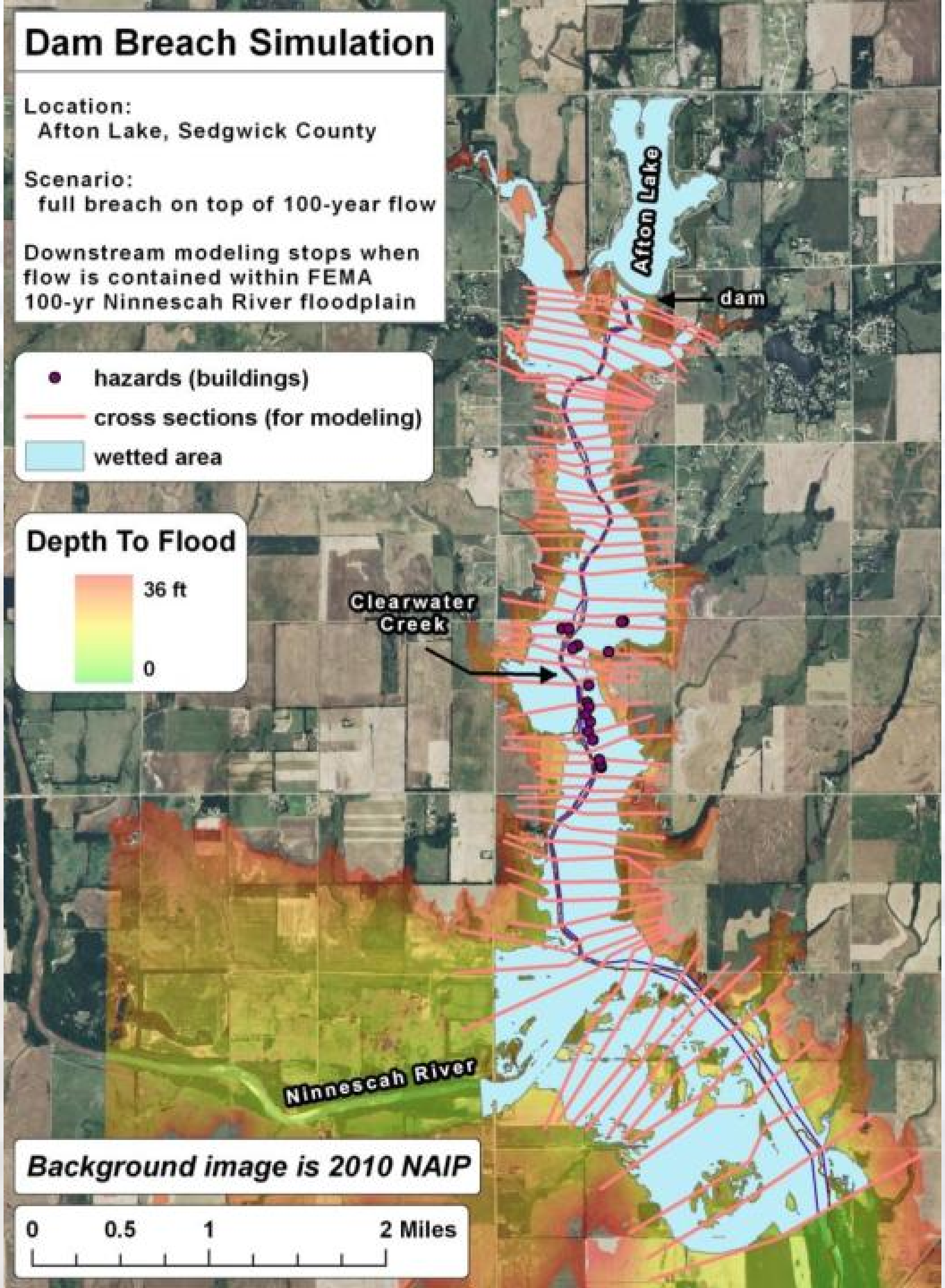
- DTF values increased more than _4 m_, indicating much less frequent reconnection to the river.

Next Step:
Relate stage to frequency

***Note:* A non-hydrologic connectivity index, such as distance-to-stream, will not pick up levee effects.**



DTF maps provide a useful guide when specifying cross sections for hydraulic modeling.



Thanks for Listening…

Any Questions?

Email: jkastens@ku.edu