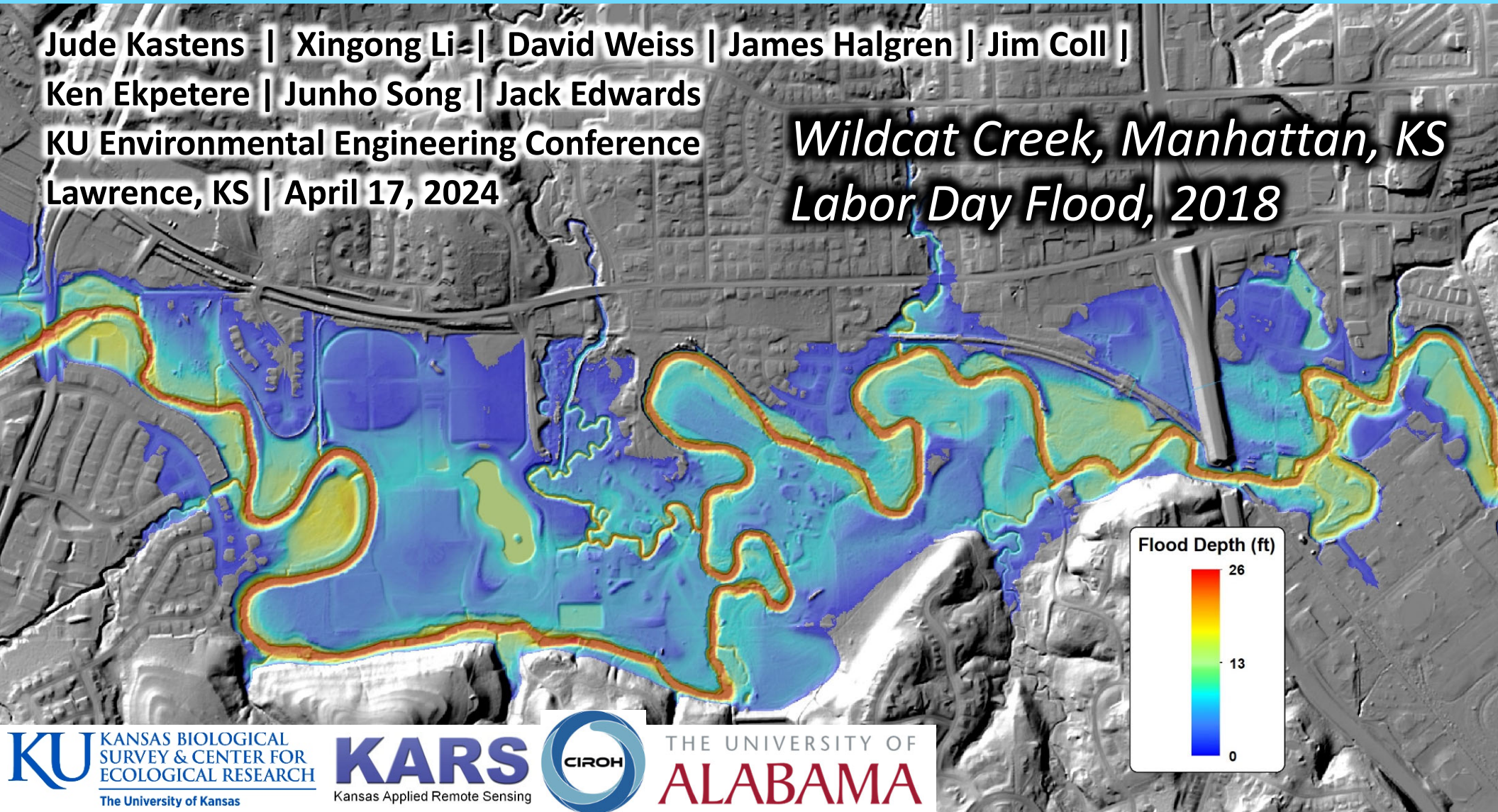
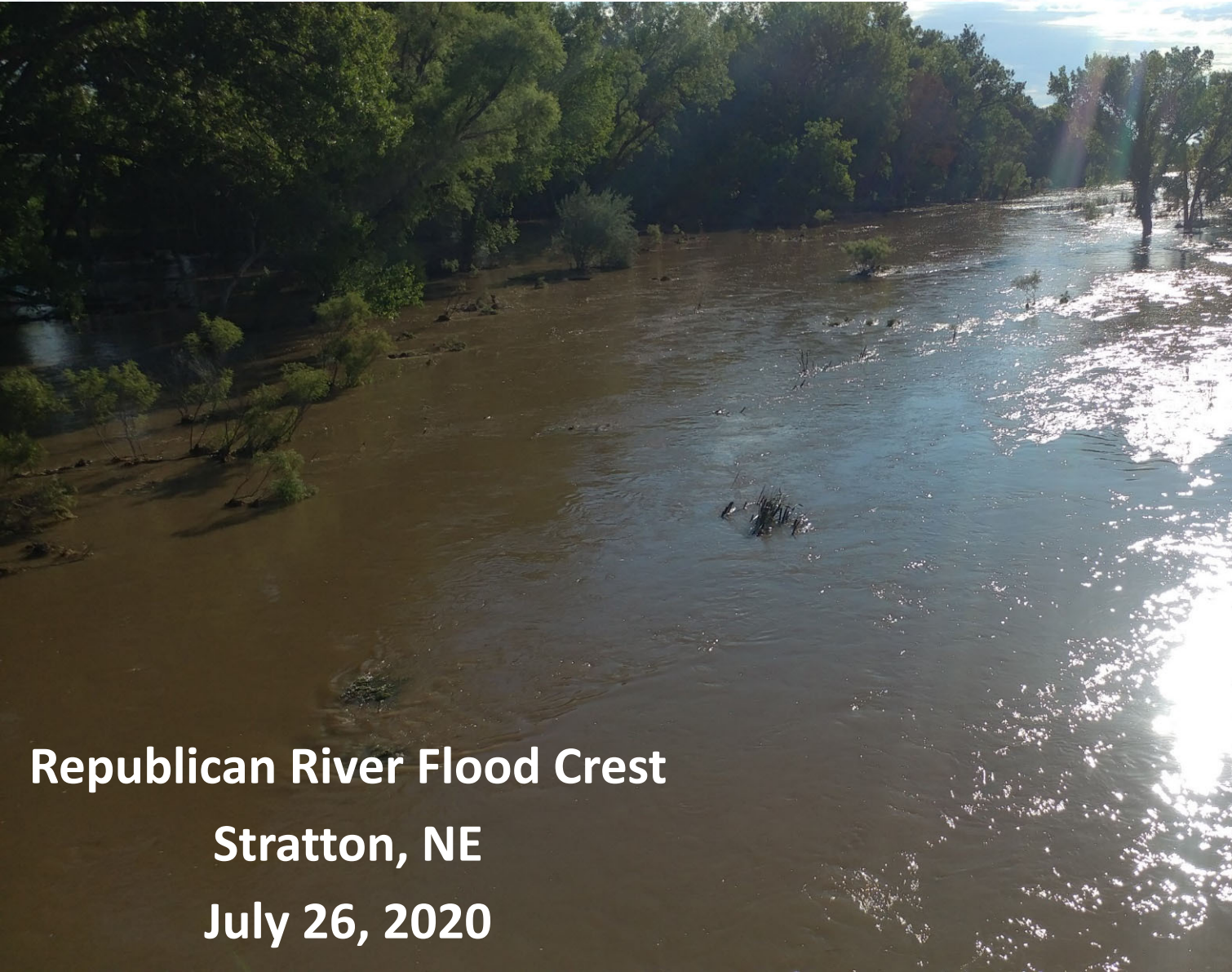


Operational Flood Inundation Mapping in Kansas & Implications for Water Infrastructure

Jude Kastens | Xingong Li | David Weiss | James Halgren | Jim Coll |
Ken Ekpeterere | Junho Song | Jack Edwards
KU Environmental Engineering Conference
Lawrence, KS | April 17, 2024

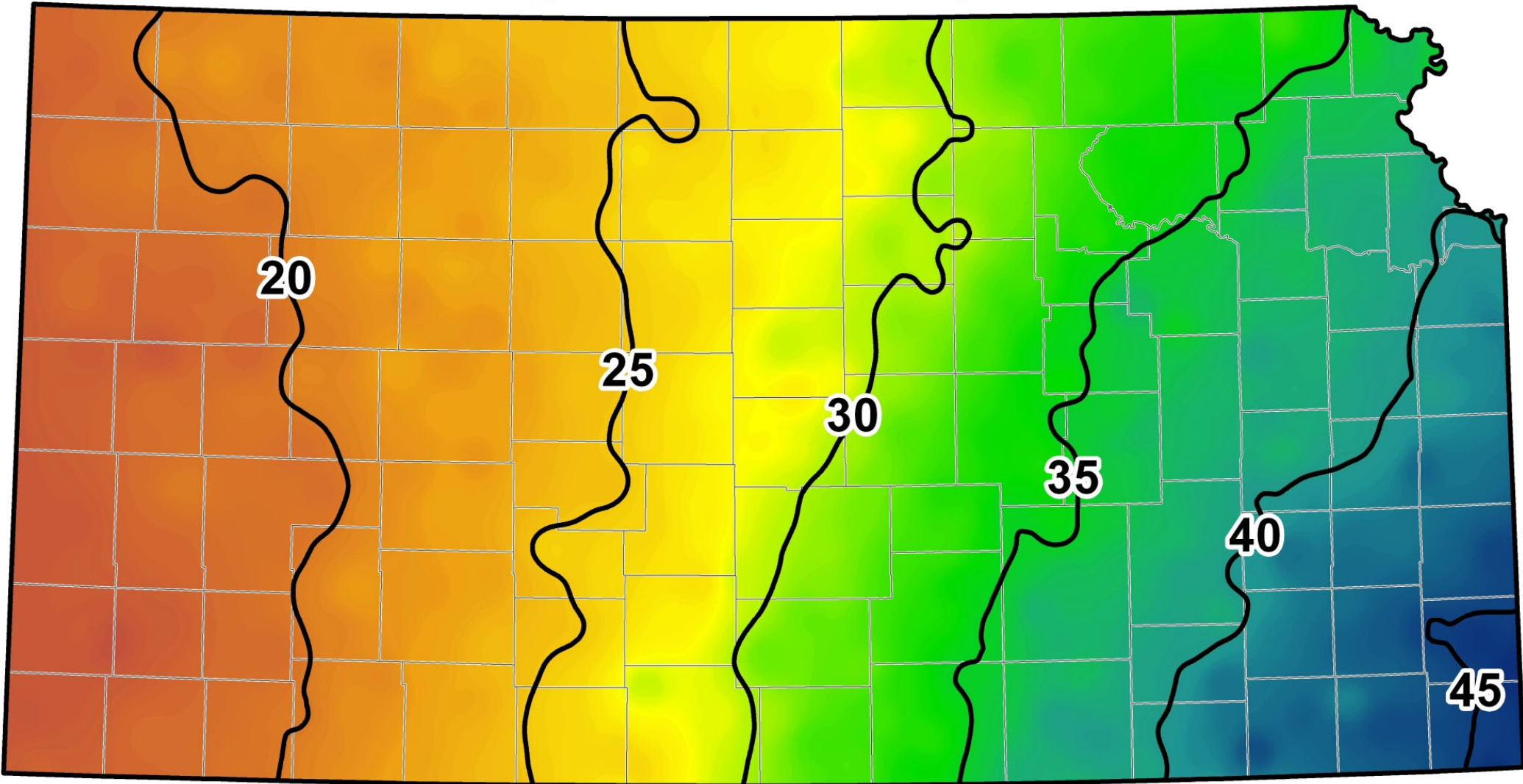
*Wildcat Creek, Manhattan, KS
Labor Day Flood, 2018*





**Republican River Flood Crest
Stratton, NE
July 26, 2020**

Average Annual Precipitation (1981-2010)



Inches

16

20

24

28

32

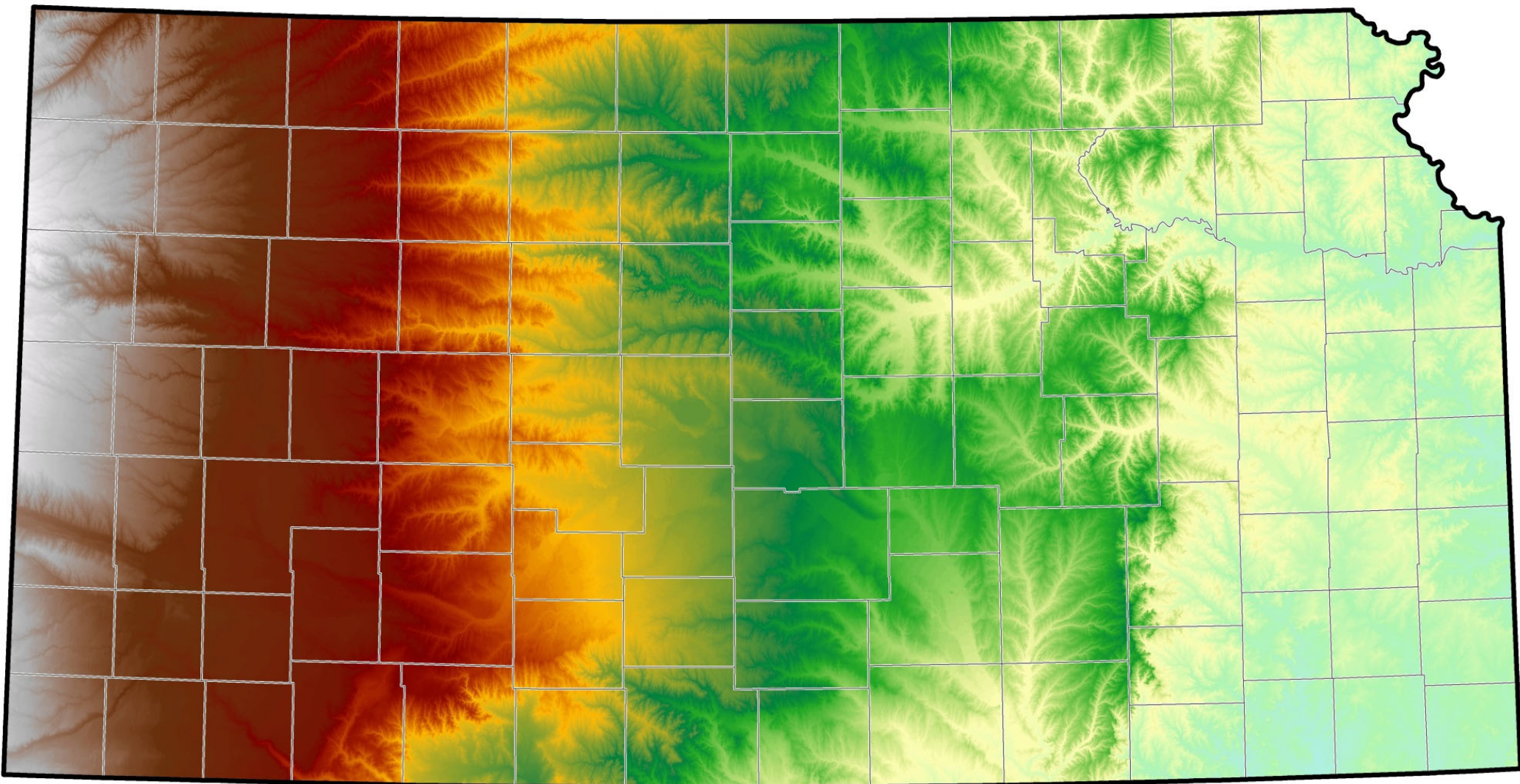
36

40

44

46

Elevation



Feet

4036

3500

3000

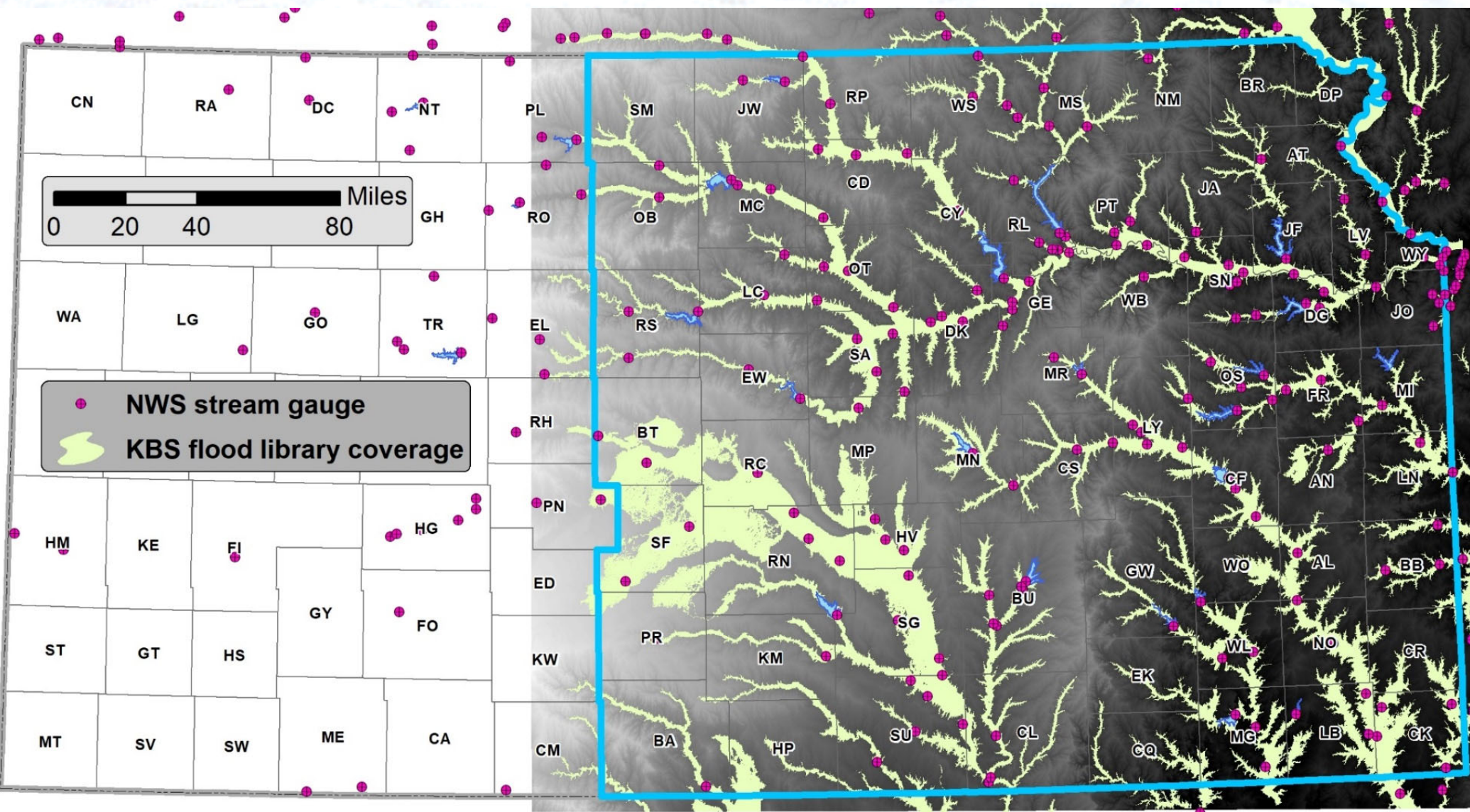
2500

2000

1500

1000

675



Kansas Inundation Library Coverage

Background



- Inundation library coverage developed for gaged stream network spanning greater eastern Kansas (GIS-PB funding 08, 09, 11, 13)
- Library put into action during record 2019 flooding
- Funding for mapping tool development provided by KWO (2020-2024) & KDEM (2020)
- **Future directions:**
 - Improved mapping capabilities, statewide coverage
 - Enhanced functionality, such as impacts to roads and other critical infrastructure

Kansas Real-Time Flood Mapping Dashboard

<https://kars.geoplatform.ku.edu/pages/kansas-inundation-mapping>

Kansas Flood Mapping Dashboard

Gauge List (sorted by flood status)

- No Flooding: Stranger Creek at Easton (ESTK1)
- No Flooding: Elm Creek (GID) at Amboy (AMBN1)
- No Flooding: Walnut River at El Dorado (EDEK1)
- No Flooding: Walnut River at El Dorado (EDWK1)
Last update: 2 seconds ago

5 of 10

ELWK1: Smoky Hill River at Ellsworth
F IVI

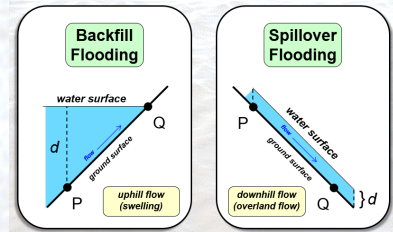
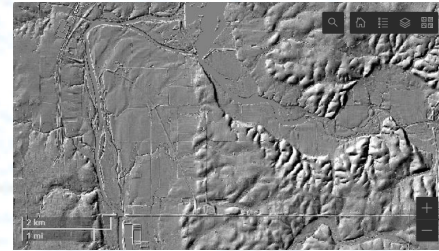
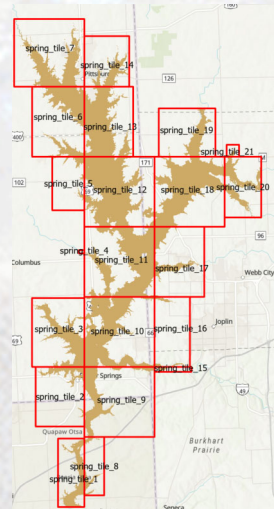
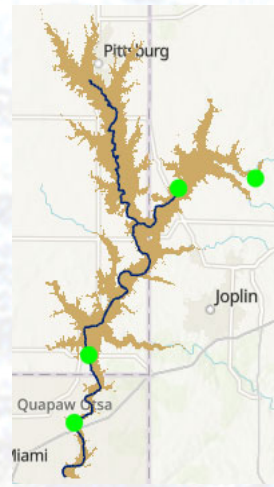
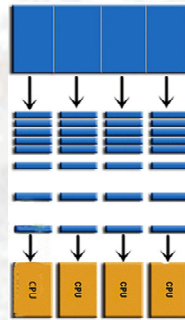
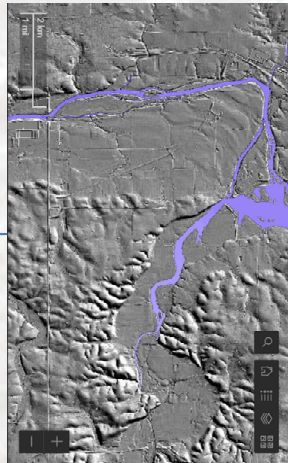
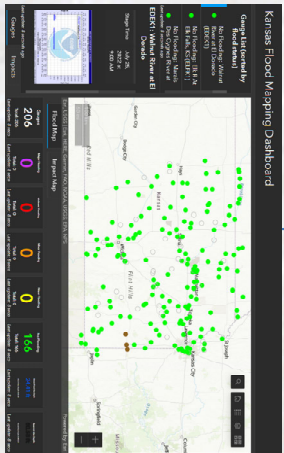
Summary:

Category	Count	Total
Gauges	206	206
Major Flooding	0	0
Moderate Flooding	0	0
Minor Flooding	0	0
Near Flooding	0	0
No Flooding	170	170

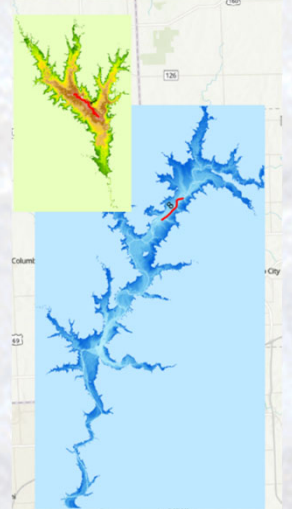
Stream Flood Max Depth: 20.34 ft
Reservoir Max Depth: 77.7 ft

Logos: KU Kansas Biological Survey & Center for Ecological Research, The University of Kansas; KARS Kansas Applied Remote Sensing

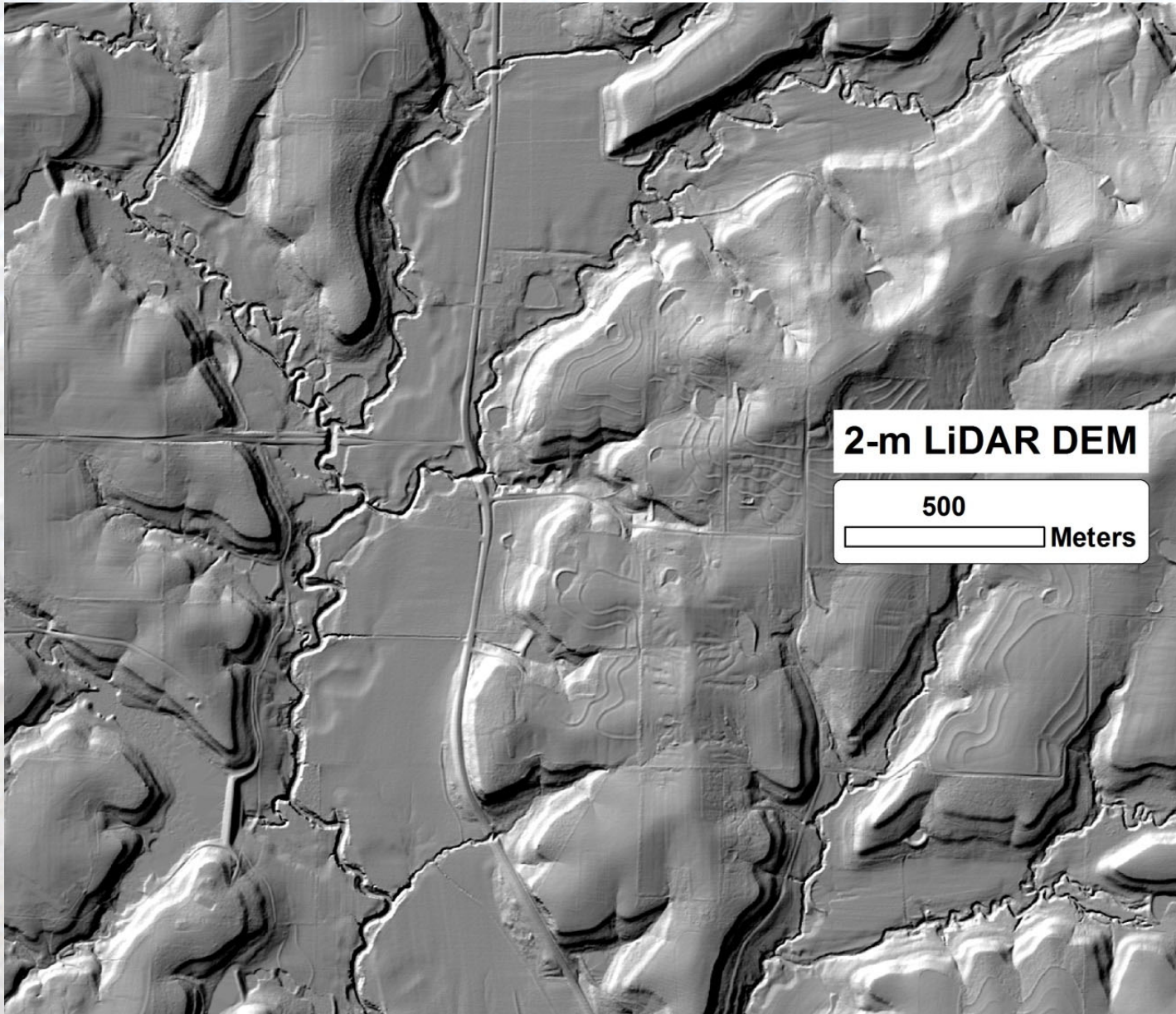
System Structure



FLDPLN



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

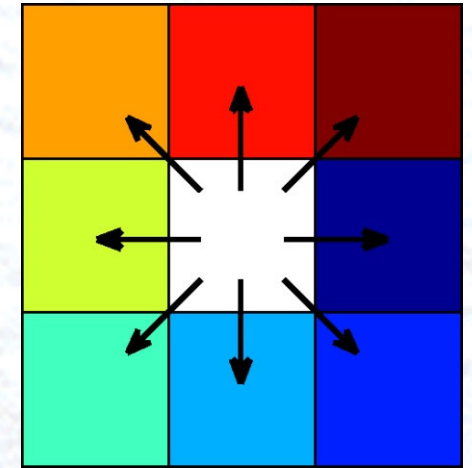
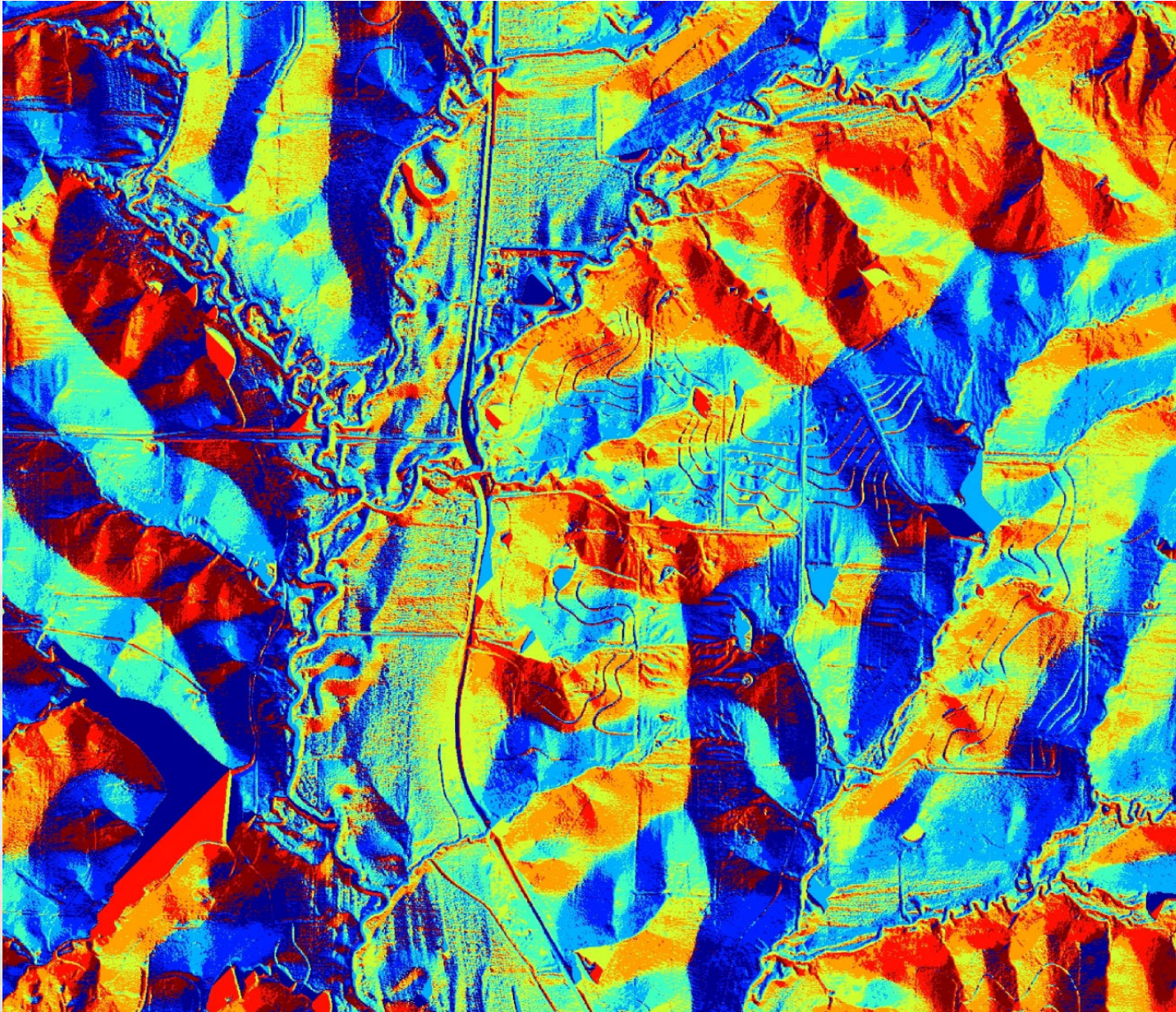


This DEM was created using LiDAR data.

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

DEM (shown in shaded relief)

Terrain Processing: **Flow Direction** (derived from filled DEM)

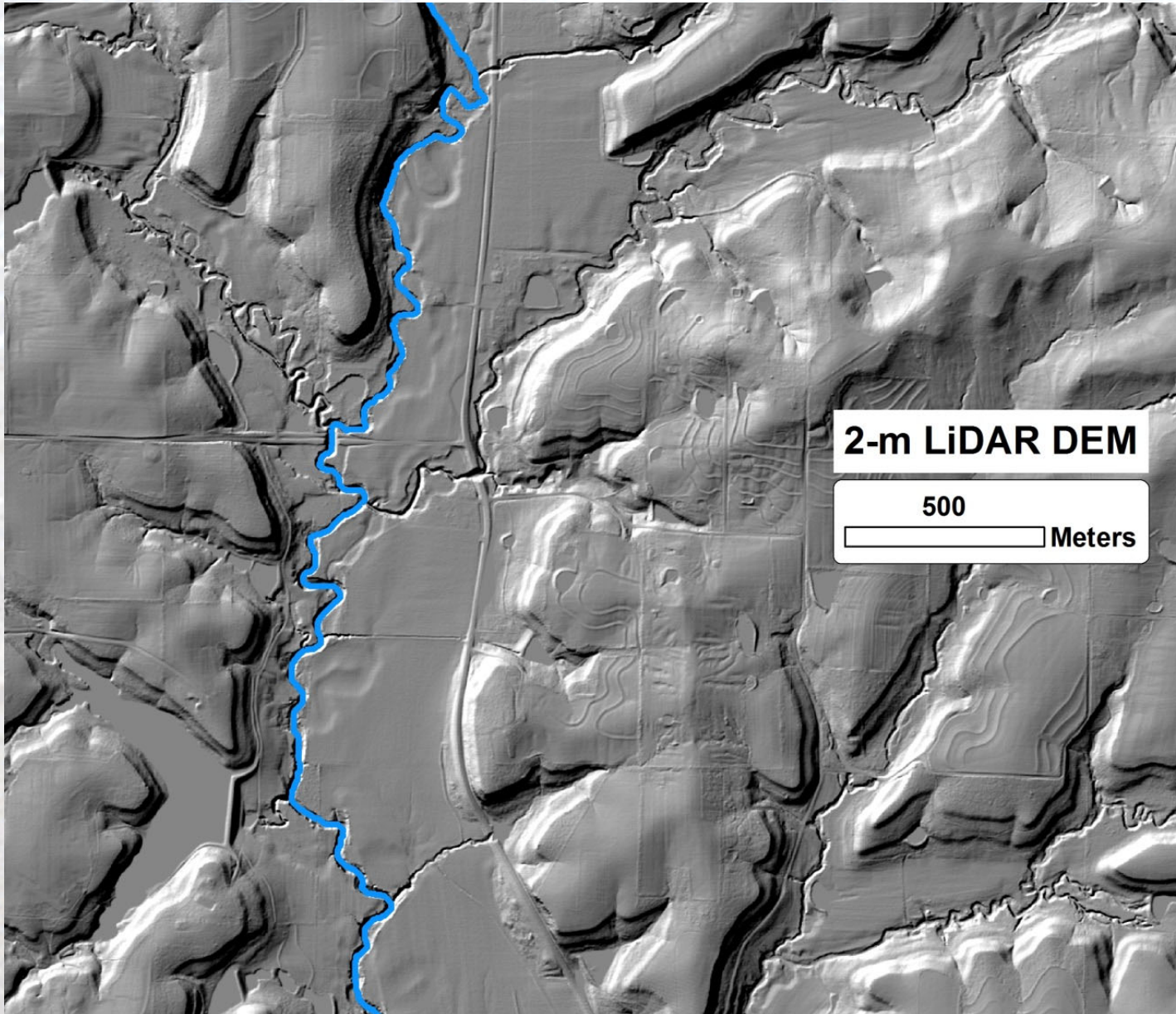


Each pixel is colored based on its flow direction.

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

Flow direction map (gradient direction approximation)

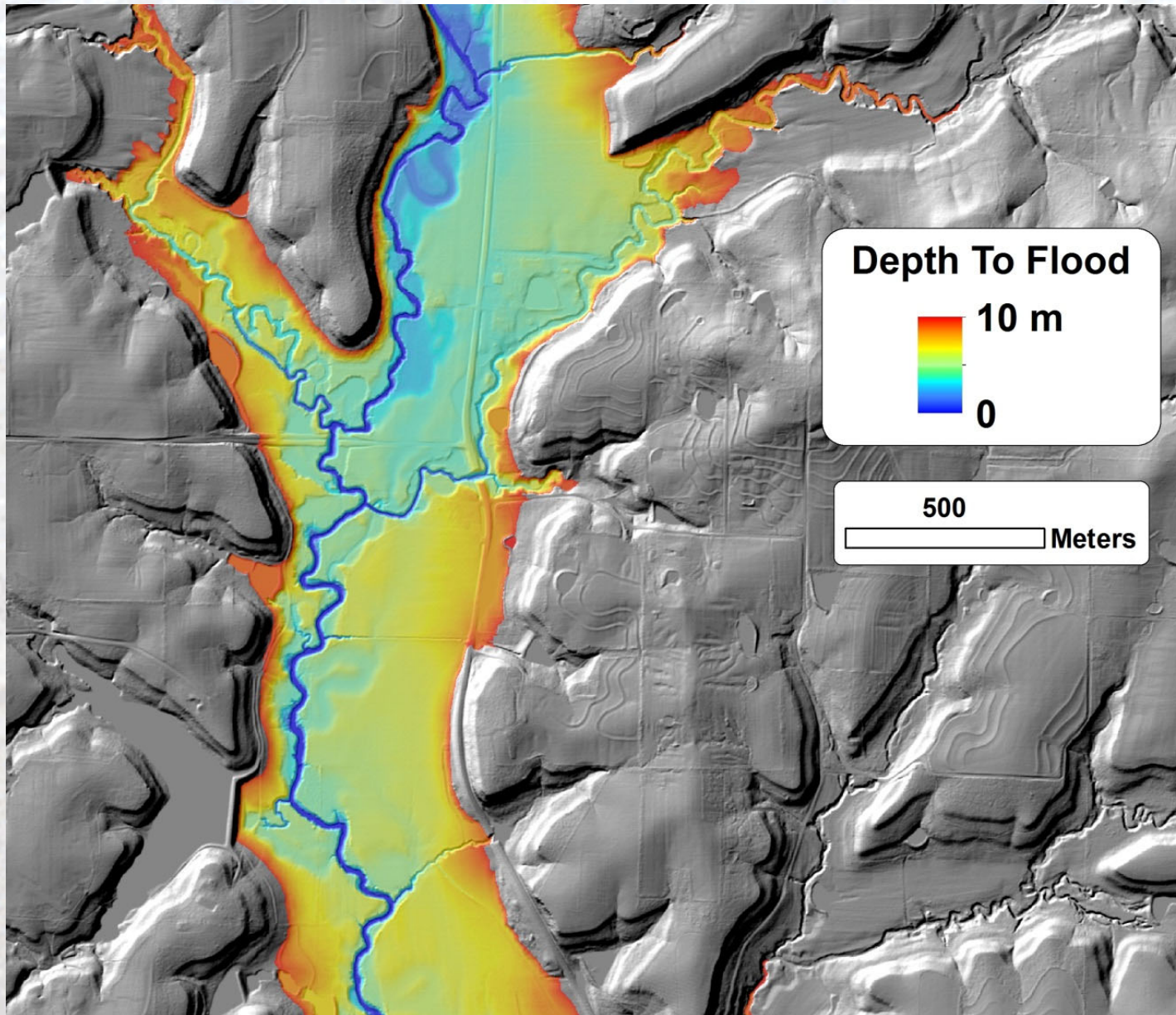
Terrain Processing: *Stream Delineation* (from Flow Direction)



The Mud Creek streamline is identified (shown in blue) using an appropriate flow accumulation threshold or starting point.

“Synthetic Stream Network”

Terrain Processing: *Floodplain Mapping*



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

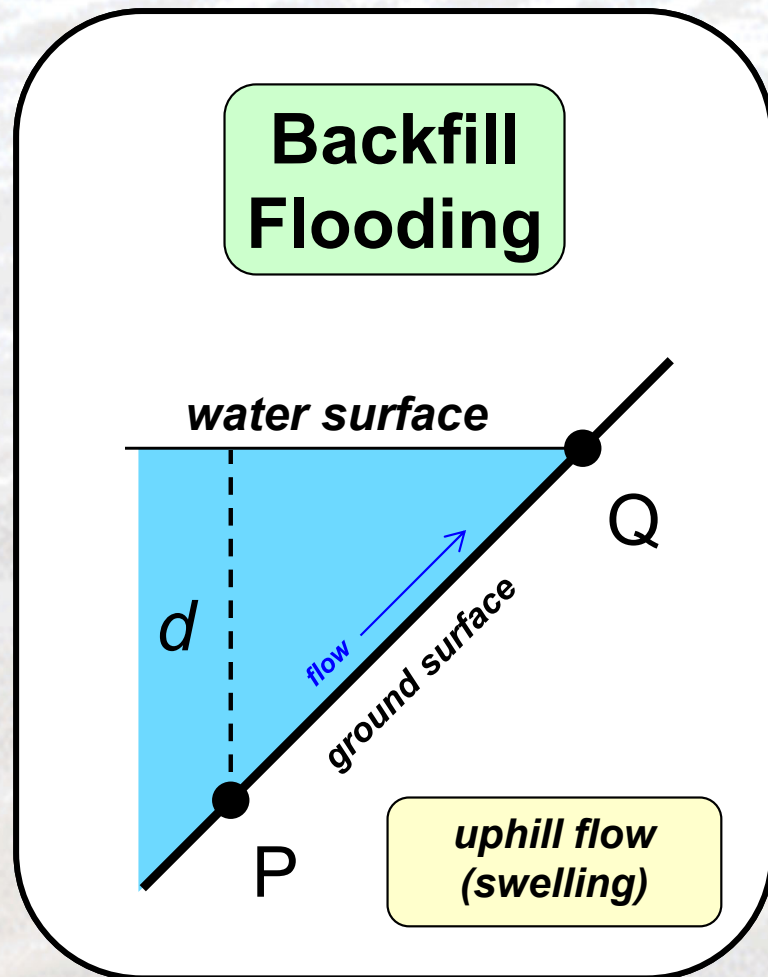
FLDPLN is a static, 2D hydrologic model that requires only DEM data as input.

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

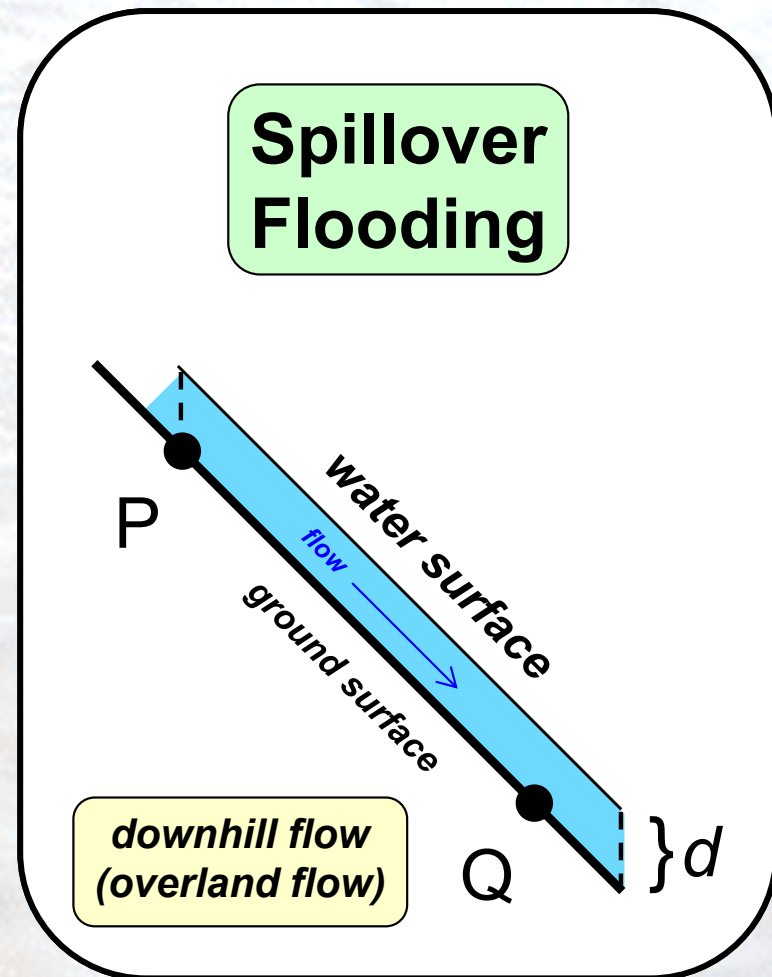
10-m Floodplain (DTF Map)

The FLDPLN (“Floodplain”) Model—

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



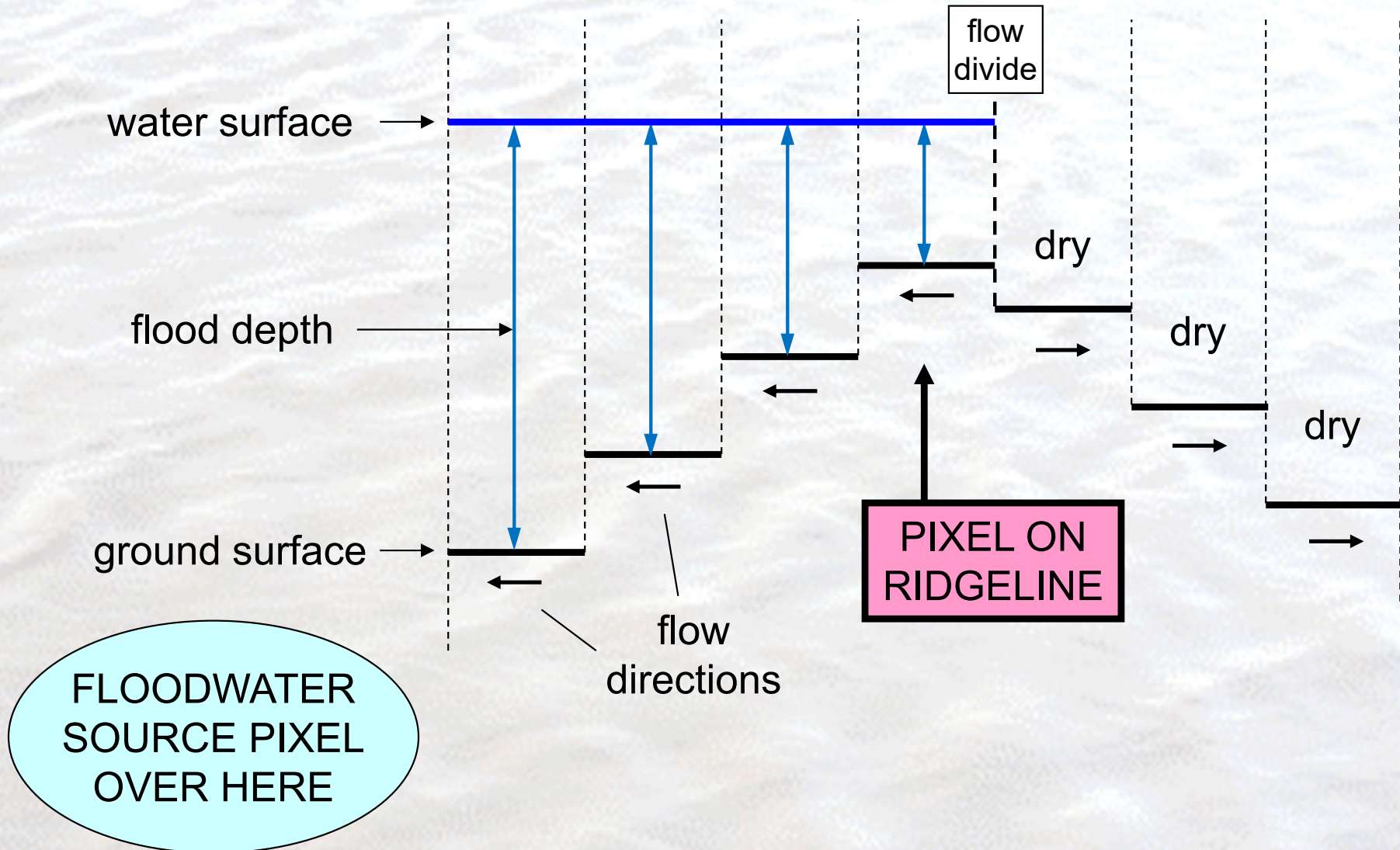
“Water seeks its own level”



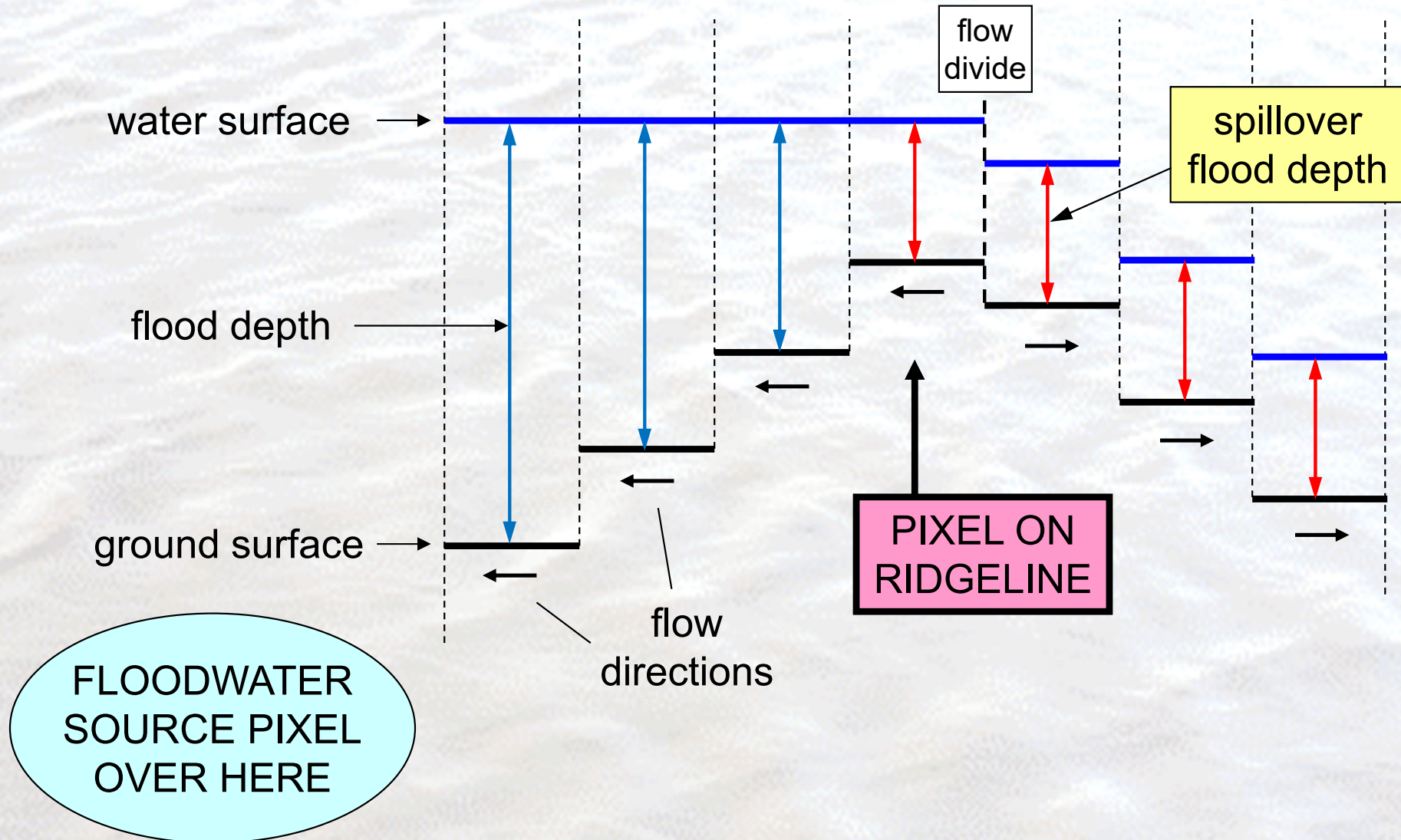
“Water flows downhill”

Backfill Flooding

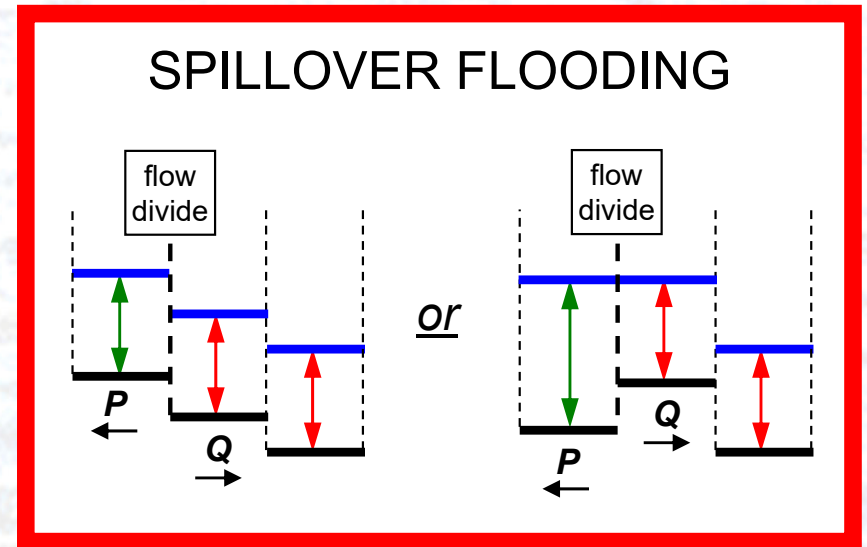
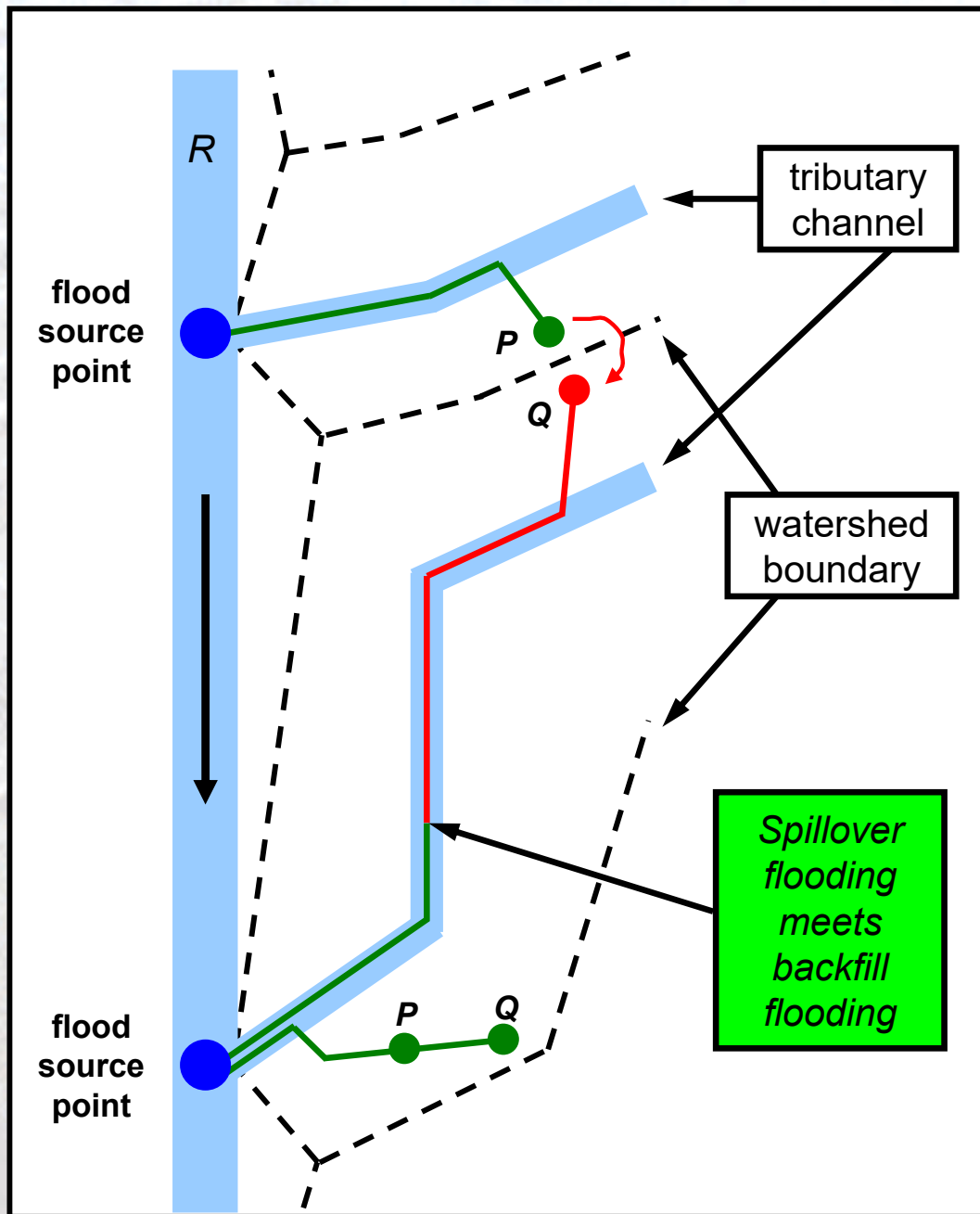
—accounts for floodwater expansion due to swelling processes



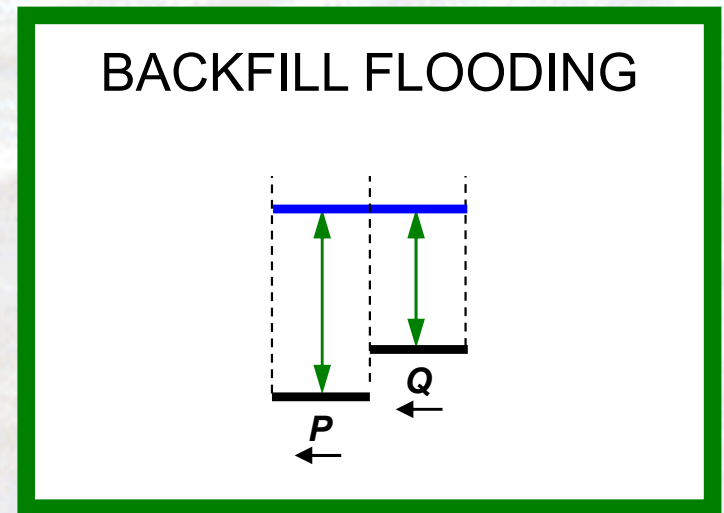
Spillover Flooding—accounts for floodwater rerouting (new flow path development)



PLAN VIEW illustrating backfill and spillover flooding



— Depth To Flood (DTF) Contour

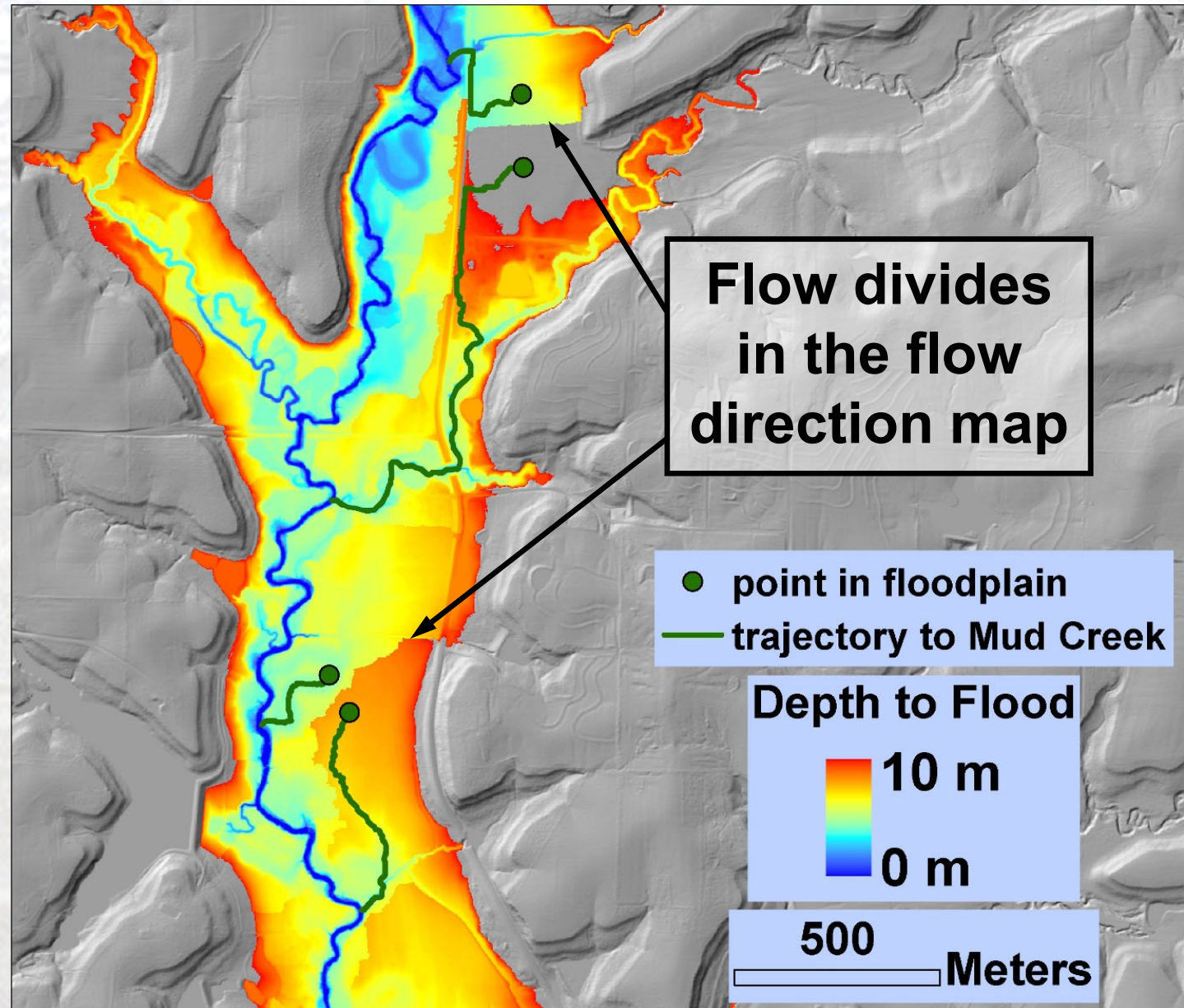


Backfill Flooding Is Not Sufficient

Here is what a DTF map looks like determined using only backfill flooding.

Note the erroneous discontinuities.

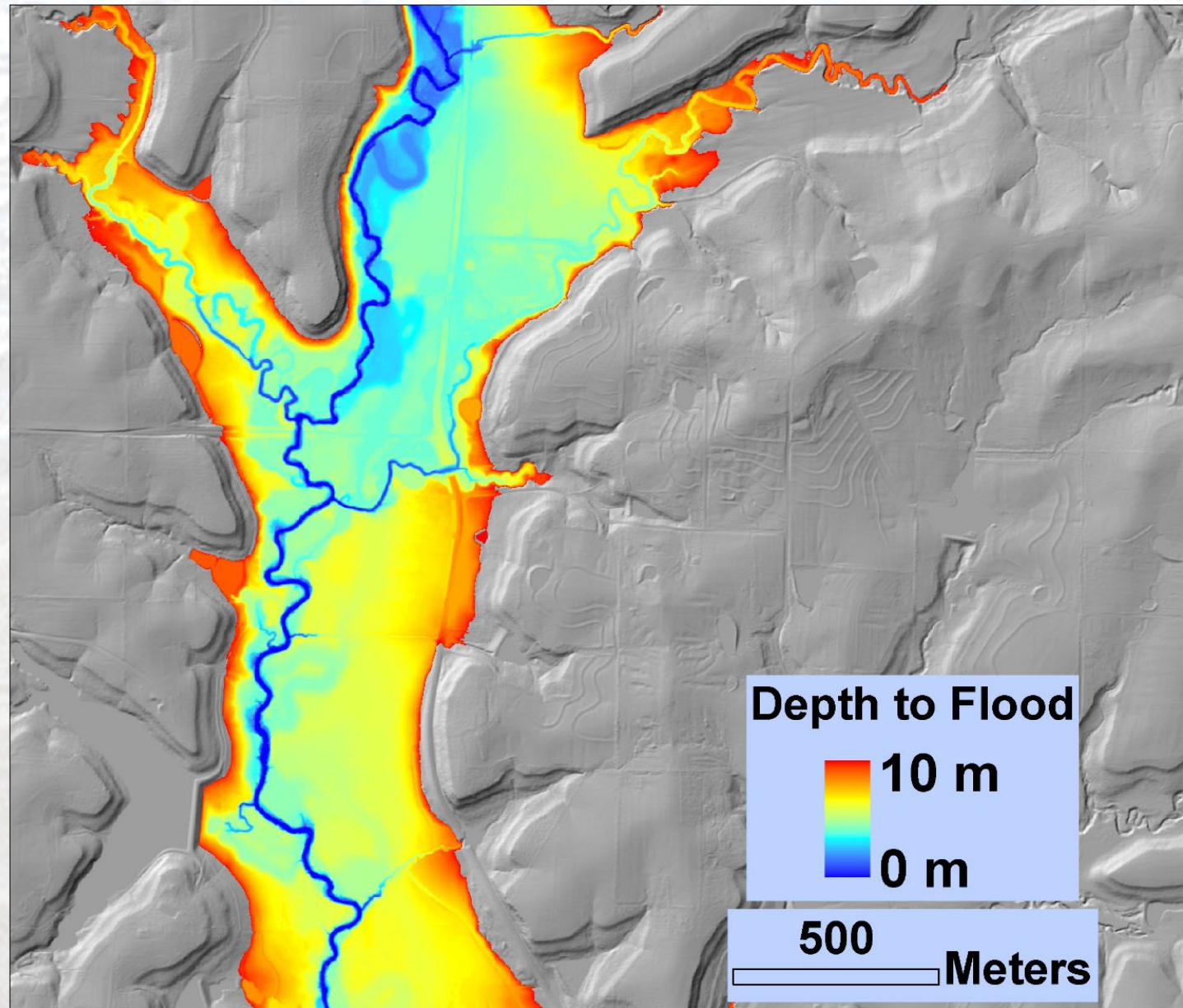
These are caused by ridgelines in the DEM.



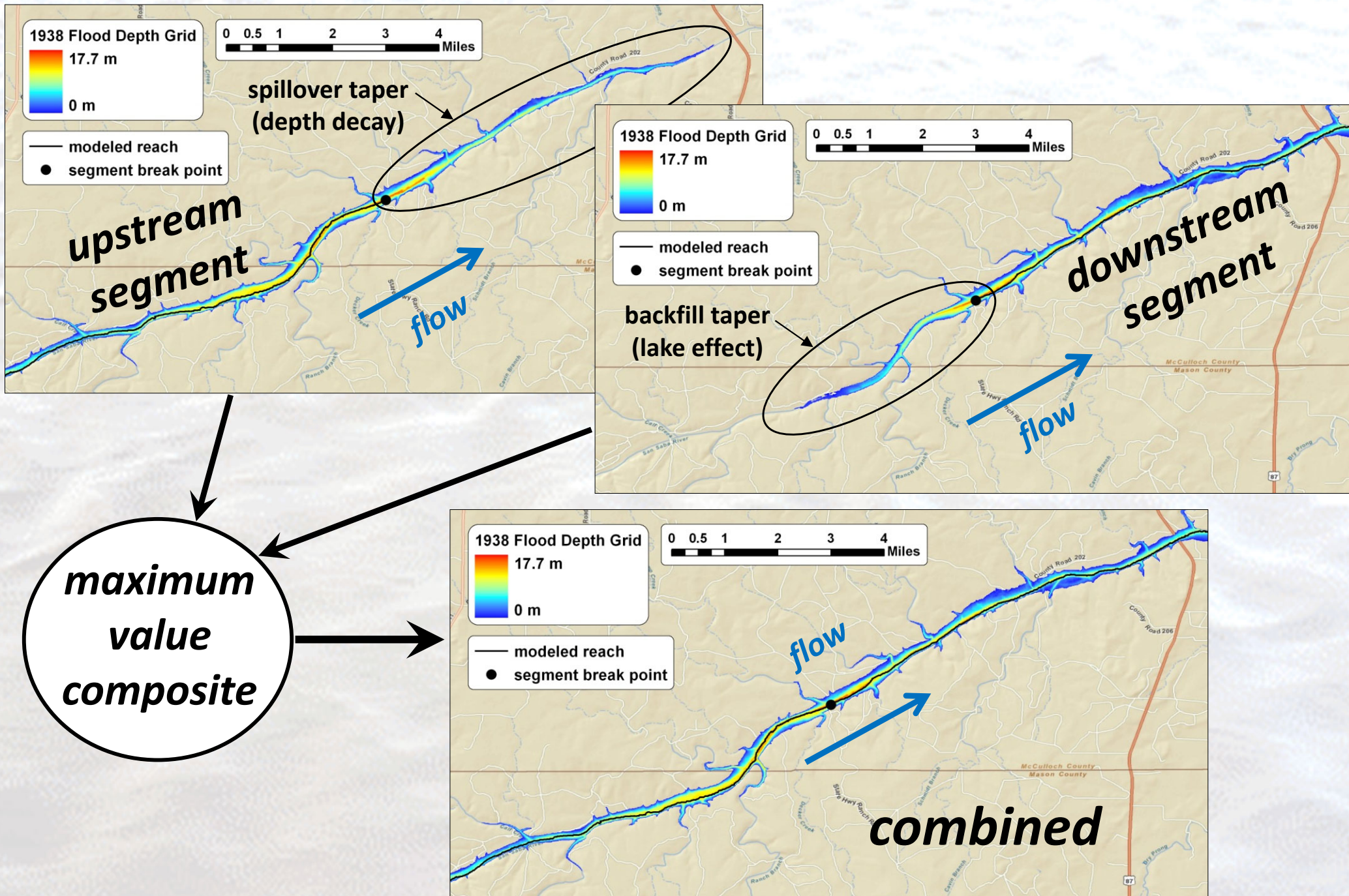
Backfill + Spillover Flooding

By backfill flooding using small flood depth increments, and allowing spillover flooding to occur on the floodplain boundary between iterations, the DTF discontinuity problem is mostly resolved.

The 10-m steady state floodplain is shown, computed using the FLDPLN model and 0.5 m increments.

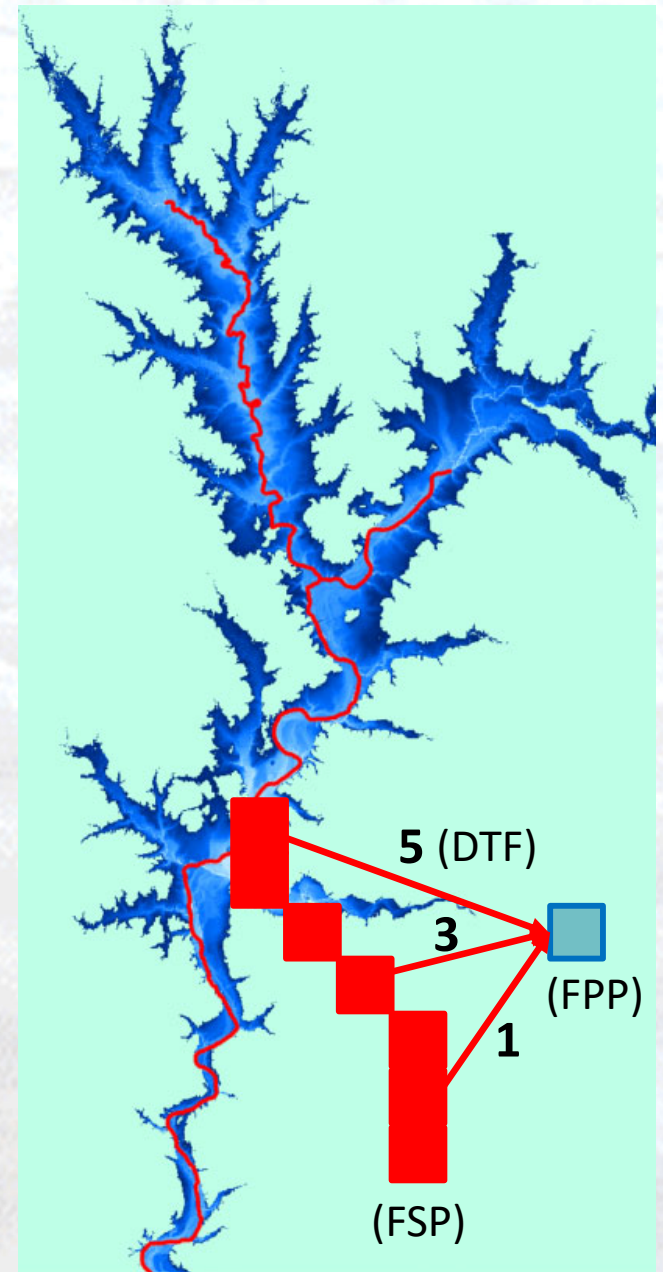


Seamless modeling with FLDPLN



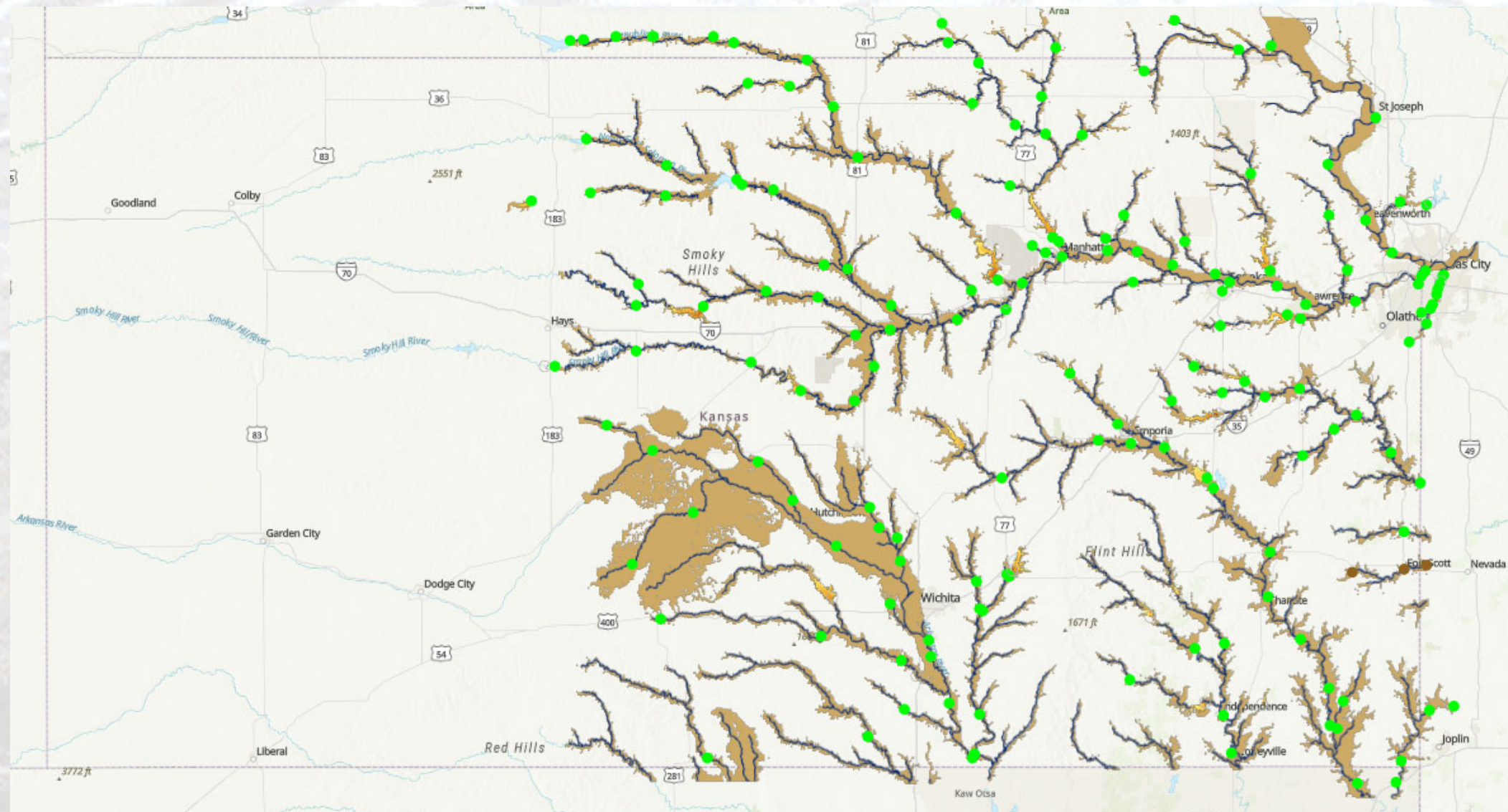
FLDPLN Model

- A floodplain pixel (FPP) can be flooded by the water originated from flood source (stream) pixels (FSPs) through backfill and spillover flooding
 - FSP-FPP flood relation
 - many-to-many relation
- Depth to flood (DTF)
 - Minimum depth at a FSP needed to flood a FPP
 - Attribute associated with a FSP-FPP relation
- FLDPLN model identifies the FSP-FPP flooding relations and their associated DTFs
 - Iterative process



FLDPLN Libraries for Eastern Kansas

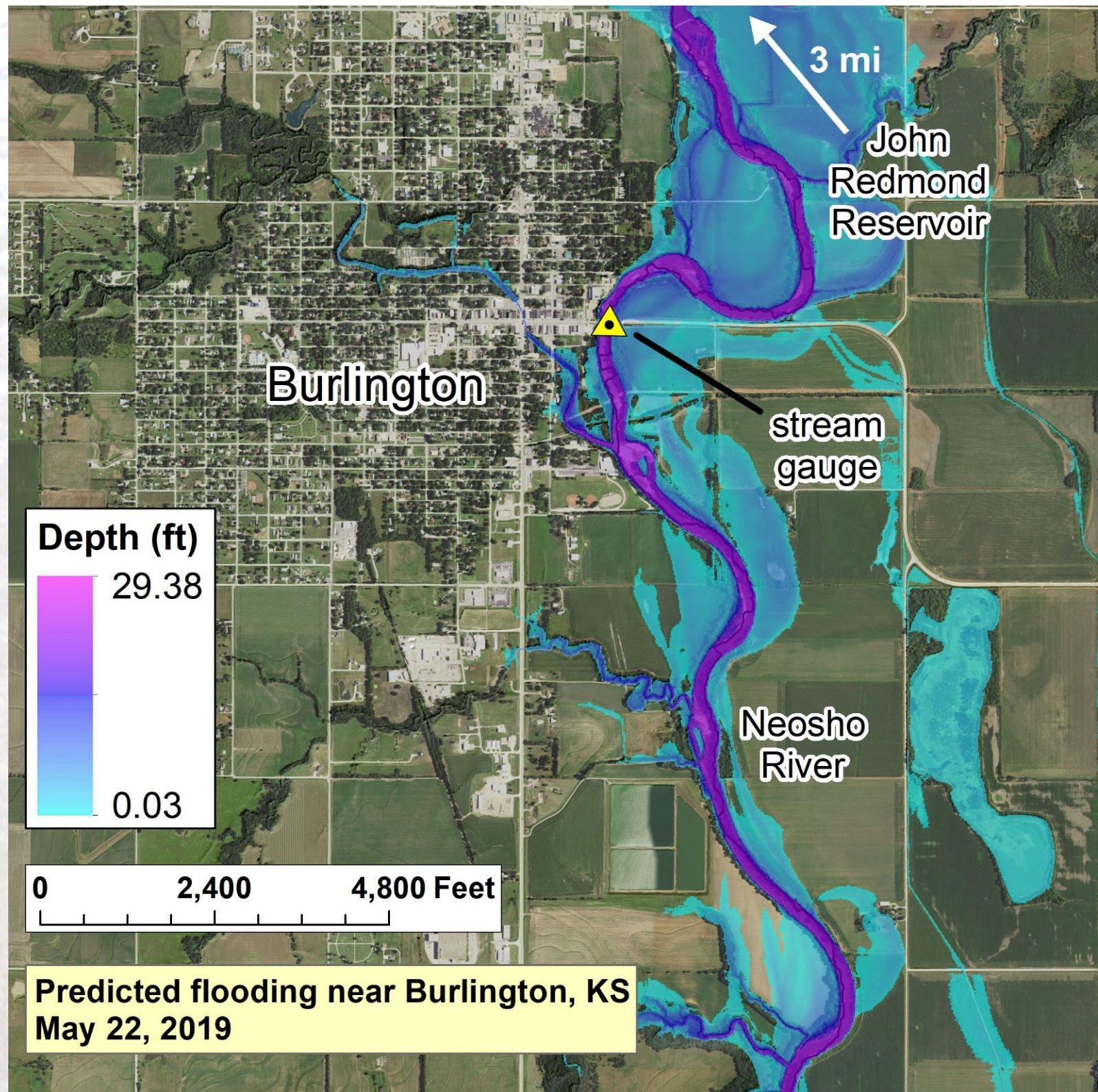
- 25 libraries cover eastern Kansas (~100 GB file size)
- Based on 5-m LiDAR DEM



Tool in Action:

Coffey Co,
KS

May 2019



Predicted flooding near Burlington, KS
May 22, 2019

KU

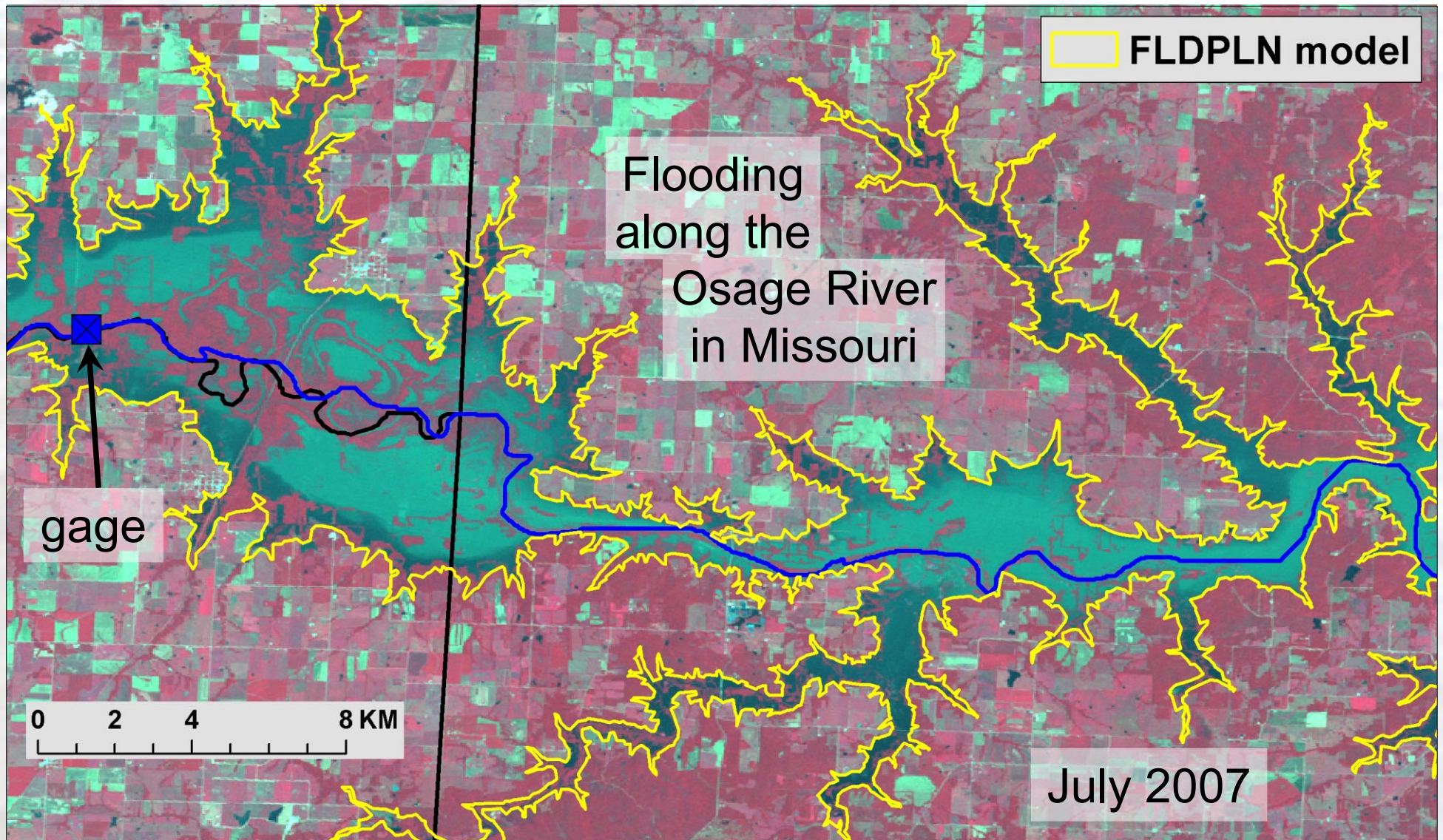
KANSAS BIOLOGICAL
SURVEY & CENTER FOR
ECOLOGICAL RESEARCH

The University of Kansas

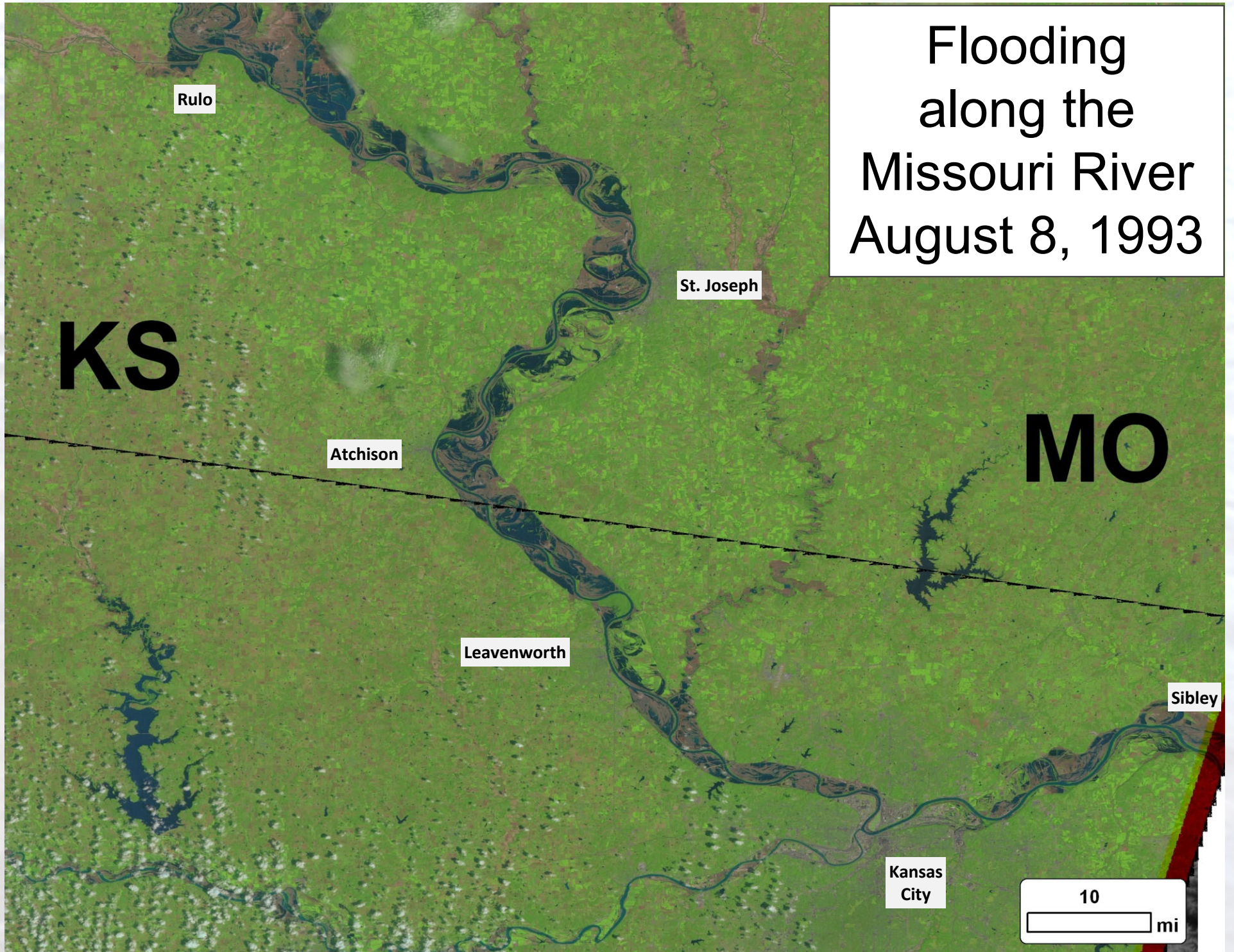
KARS

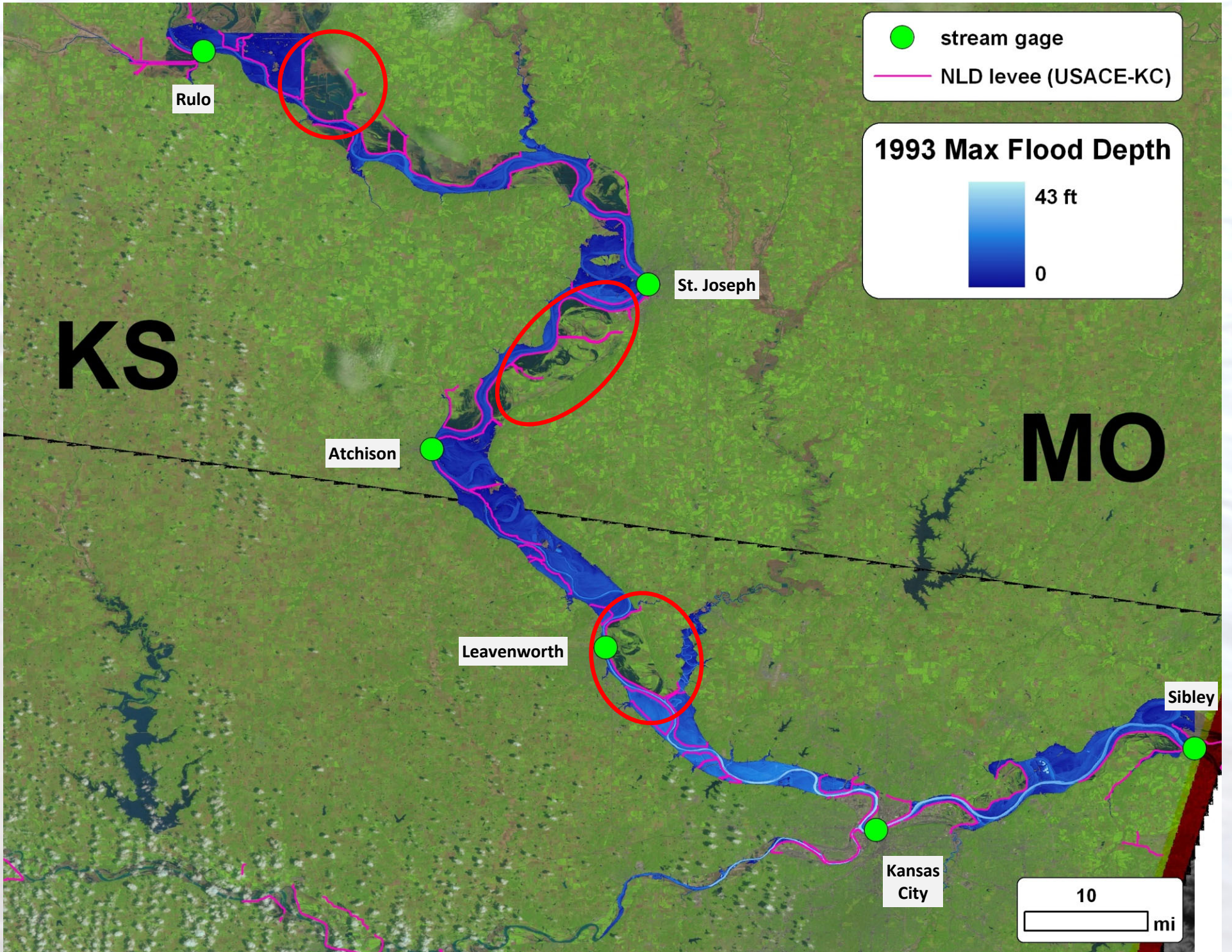
Kansas Applied Remote Sensing

Flood mapping examples using FLDPLN



Flooding along the Missouri River August 8, 1993





Wildcat Creek Flood, September 3, 2018

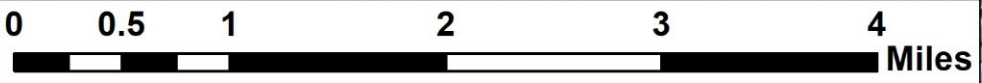
USGS: 6879805
Wildcat C at Keats
NWS: WKCK1



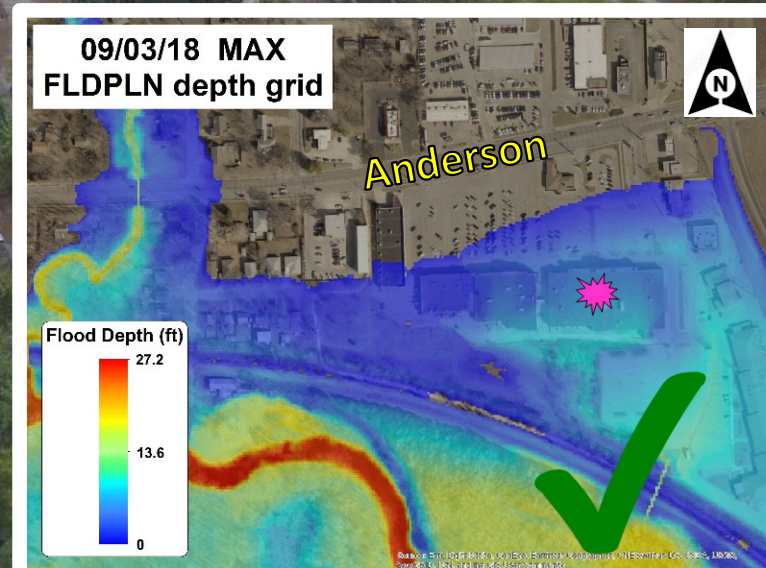
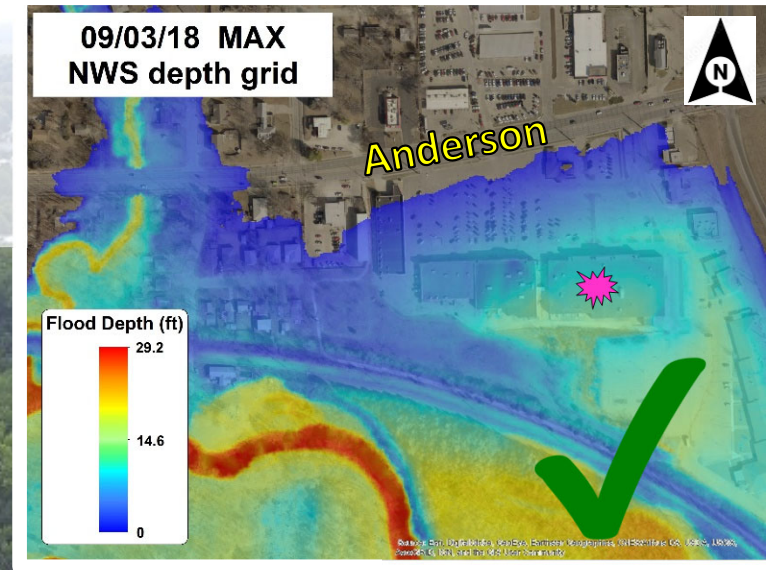
USGS: 6879815
Wildcat C at Seth Childs Rd
NWS: MSTK1



USGS: 6879810
Wildcat C at Scenic Dr
NWS: MWCK1

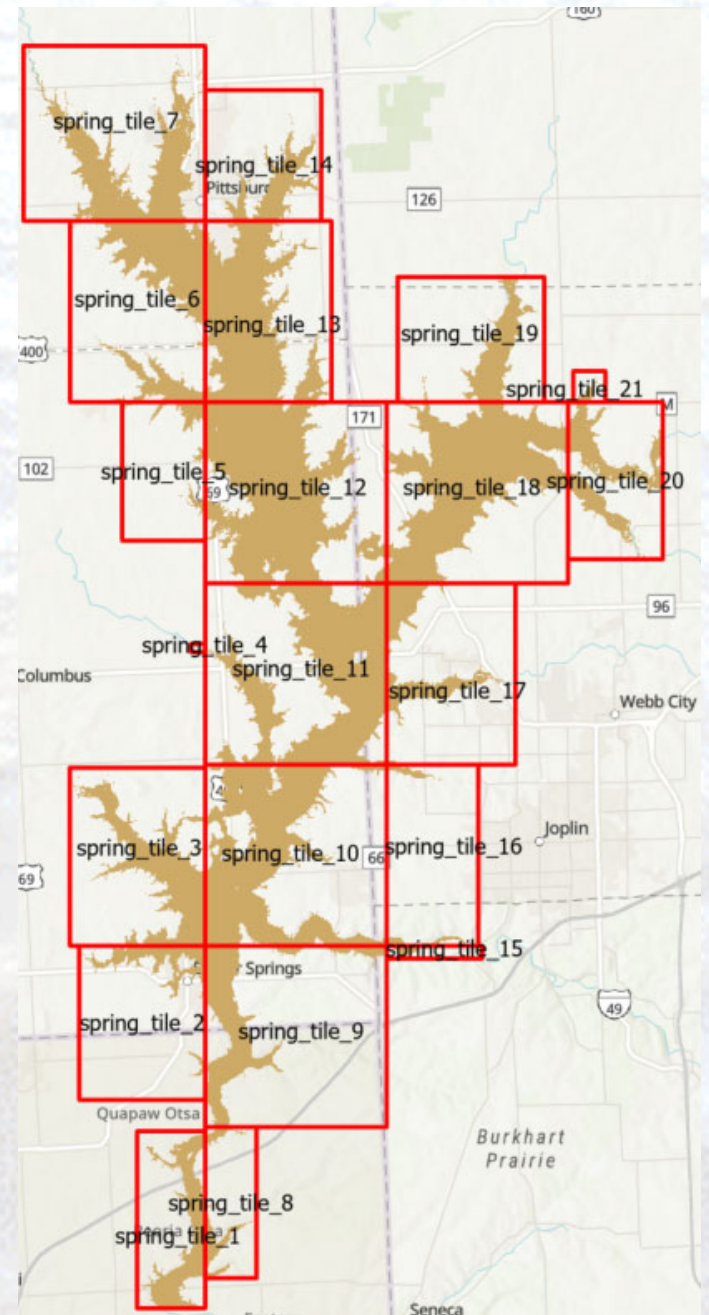


Anderson Ave & Meadowbrook Ln (looking east)



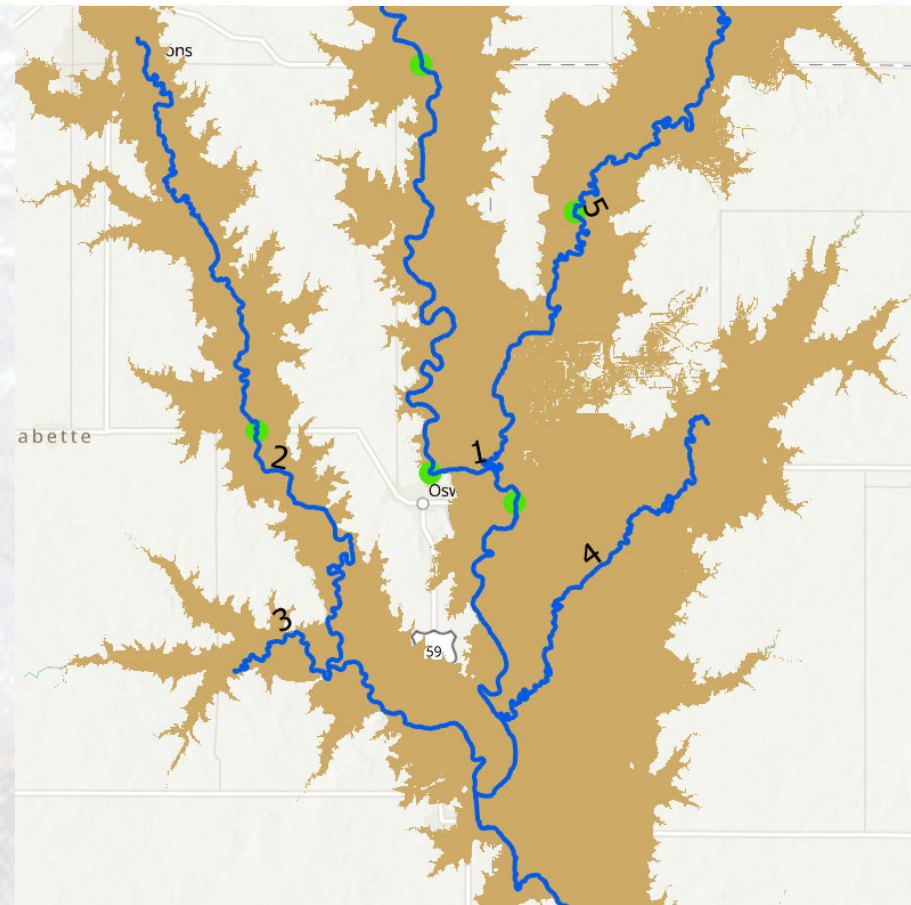
Tile FSP-FPP Relations

- Organize relations by tiles
 - Each tile stores **all the FSPs** that can flood the FPPs in the tile
- Flood mapping by tiles
 - Avoid memory overflow with a proper tile size
 - Only one file I/O is needed to map a tile
 - Scalable
 - Mapping tiles in parallel
 - Each tile can be mapped independently



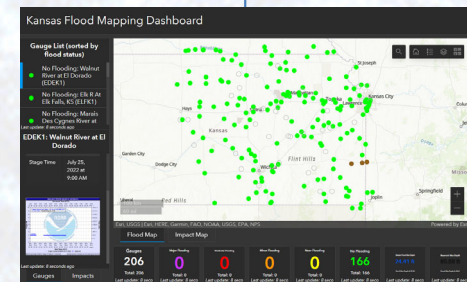
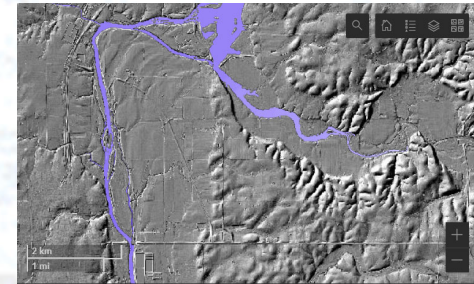
Gauge and Stage

- Reliable means for flood tracking
- Estimate FSP depth of flow (DOF)
 - Snap gauges to FSPs
 - Based on stream orders
 - From low to high
 - Linear interpolation using distance or elevation
 - Better yet, use the 100-year flood profile to interpolate stage values between gauges
- Sources
 - NWS AHPS and USGS
 - State and local networks
 - Bridge gauges



Serve Flood Maps on Web

- Accessible to KDEM and the general public
 - Don't need to run flood mapping locally
 - Available through the dashboard or as a service
 - Take advantage (scalable) of cloud cyber infrastructure
- Flood maps are served using ArcGIS Server
 - Tiled flood maps (COGs) are served as ArcGIS image services using mosaic datasets
 - Base maps are served as ArcGIS map or image services
- Stream flood maps are updated hourly
- Reservoir flood maps are updated every 6 hours



Kansas Flood Mapping Dashboard

Stream Flood Depth (Nowcast)

(1-hr refresh)

Gauge List (sorted by flood status)

- No Flooding: Kansas River at Manhattan (MHKK1)
- Unknown: Wildcat Creek at Manhattan Seth Childs Rd (MSTK1)

Last update: 7 seconds ago

1 of 2

MHKK1: Kansas River at Manhattan

Flood Status	No Flooding
Stage (ft)	5.05
Flood Status Code	5
Stage Time	November 16, 2022 at 3:45 AM

Last update: 7 seconds ago

KANSAS RIVER AT MANHATTAN
Universal Time (UTC)

Last update: 7 seconds ago

Gauges **Impacts**

Gauges	Major Flooding	Moderate Flooding	Minor Flooding	Near Flooding	No Flooding	Stream Flood Max Depth	No Reservoirs
2	0	0	0	0	1	8.81 ft	No Reservoirs
Total: 206	Total: 0	Total: 0	Total: 0	Total: 0	Total: 165	Overl Max Depth: 8.2049	
Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago	Last update: 7 seconds ago

Here, choppy depth grid based on old LiDAR (not hydroflattened)

Library refresh using latest LiDAR is underway

Kansas Flood Mapping Dashboard

Reservoir Depth

(bathymetry + LiDAR, 6-hr refresh)



Kansas Flood Mapping Dashboard

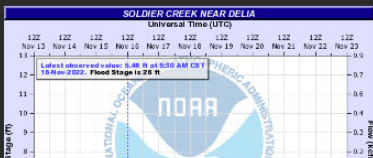
Gauge List (sorted by flood status)

- No Flooding: Soldier Creek at Delia (DELK1)
- No Flooding: Kansas River at Belvue (BVUK1)
- No Flooding: Cross Creek at Rossville (RSSK1)
- No Flooding: Rock Creek at Louisville (LISK1)
- No Flooding: Mill Creek (PXCK1) at
Last update: 10 seconds ago

◀ 1 of 10 ▶

DELK1: Soldier Creek at Delia

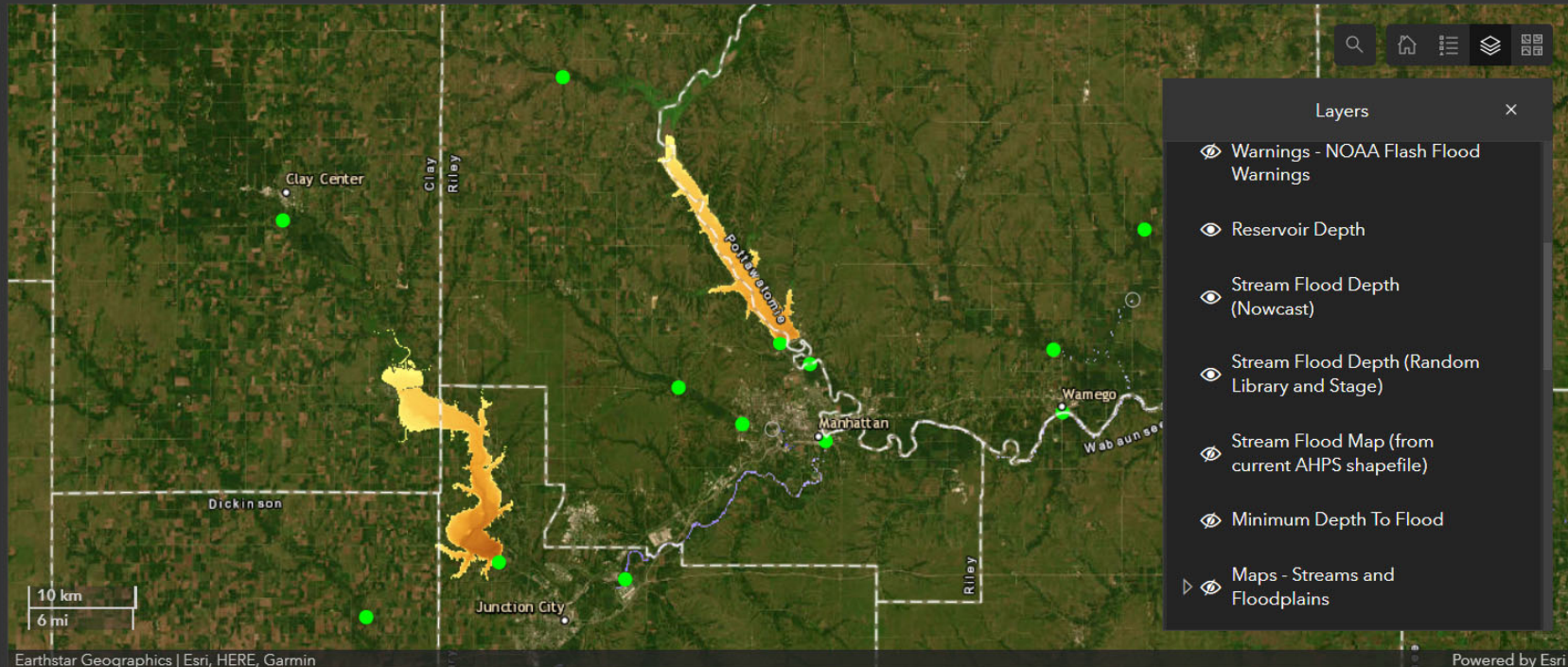
Flood Status	No Flooding
Stage (ft)	5.46
Flood Status Code	5
Stage Time	November 16, 2022 at 4:30 AM



Last update: 10 seconds ago

Gauges

Impacts



Layers

- Warnings - NOAA Flash Flood Warnings
- Reservoir Depth
- Stream Flood Depth (Nowcast)
- Stream Flood Depth (Random Library and Stage)
- Stream Flood Map (from current AHPS shapefile)
- Minimum Depth To Flood
- Maps - Streams and Floodplains

Flood Map

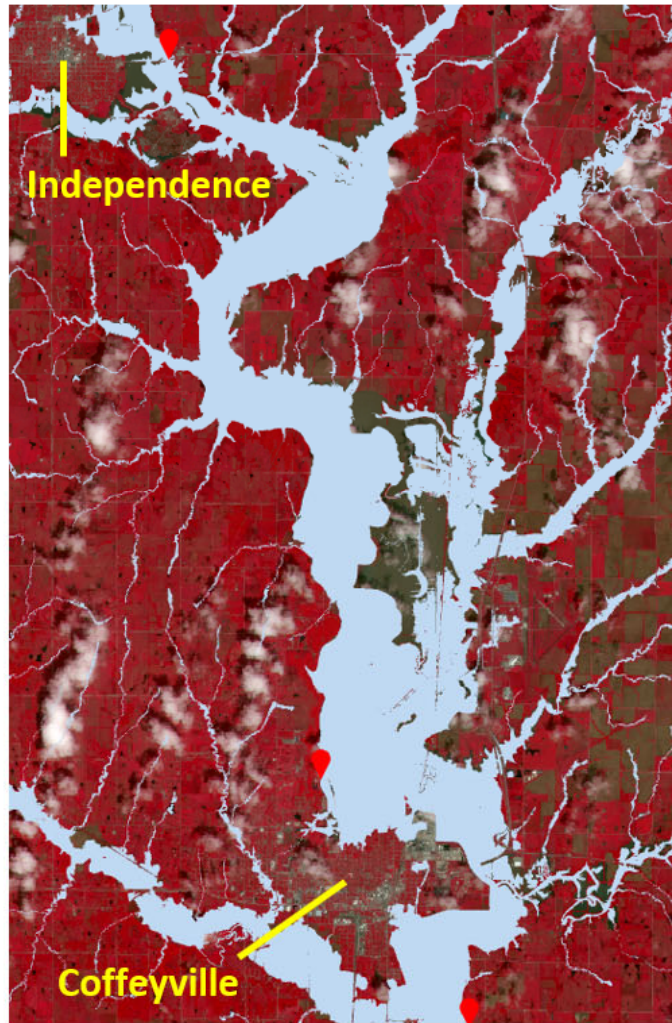
Impact Map

Gauges 19 Total: 206 <small>Last update: 10 seconds ago</small>	Major Flooding 0 Total: 0 <small>Last update: 10 seconds ago</small>	Moderate Flooding 0 Total: 0 <small>Last update: 10 seconds ago</small>	Minor Flooding 0 Total: 0 <small>Last update: 10 seconds ago</small>	Near Flooding 0 Total: 0 <small>Last update: 10 seconds ago</small>	No Flooding 17 Total: 165 <small>Last update: 10 seconds ago</small>	Stream Flood Max Depth 14.93 ft Overall Max Depth: ft 20.49 <small>Last update: 10 seconds ago</small>	Reservoir Max Depth 63.47 ft Overall Max Depth: ft 78.73 <small>Last update: 10 seconds ago</small>
---	--	---	--	---	--	--	---

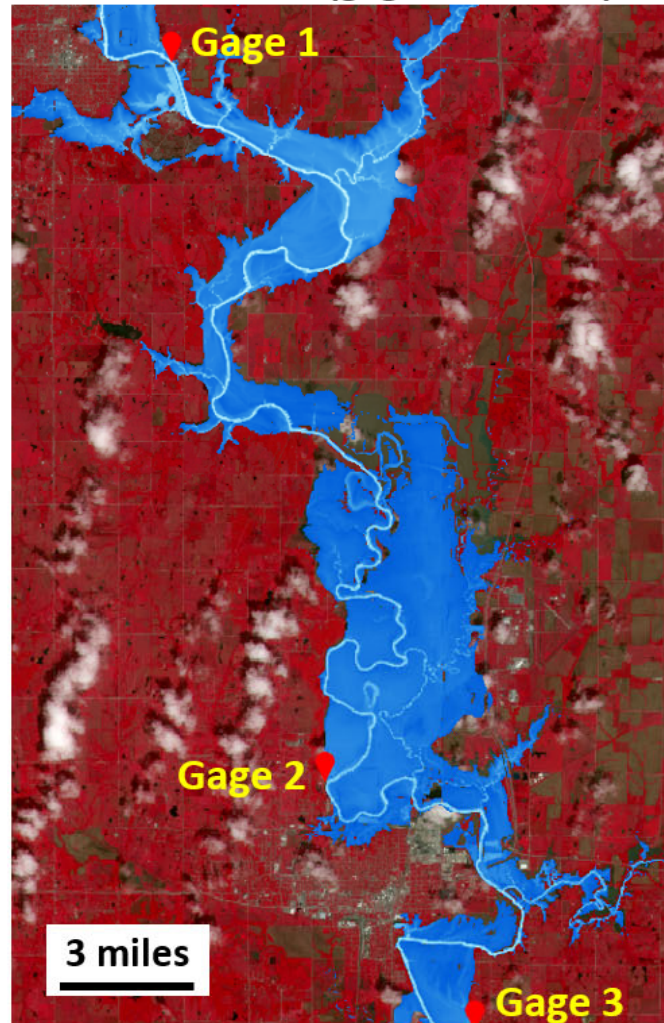
Better model, better calibration...better map

Simulation of peak 2019 flooding along the Verdigris River in Montgomery County, Kansas

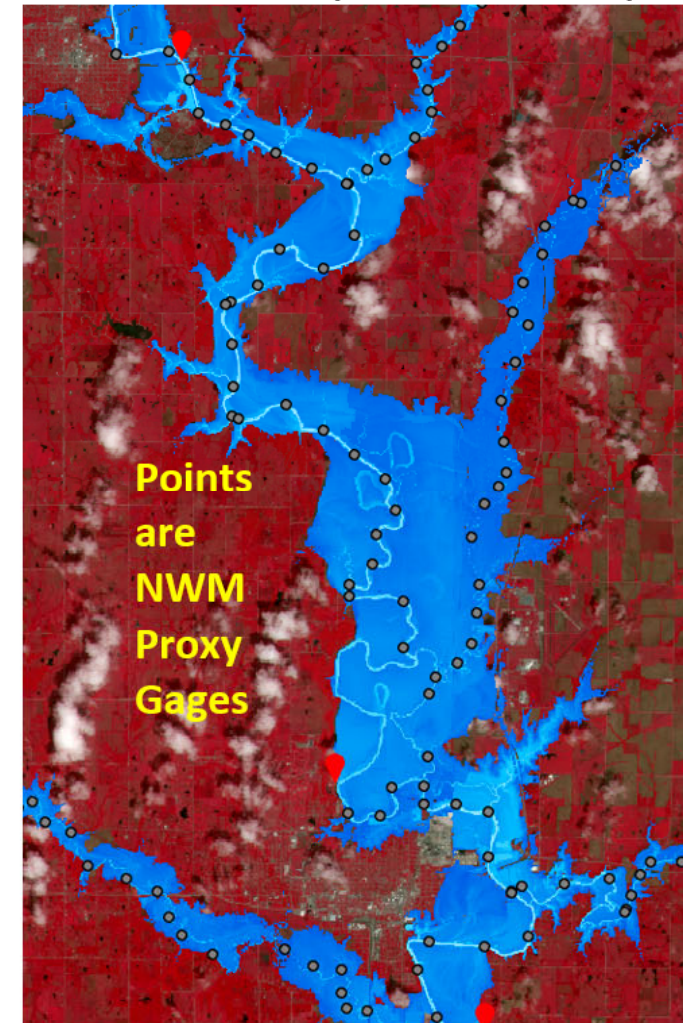
National Model (NWM calibrated)



Kansas Model (gage calibrated)



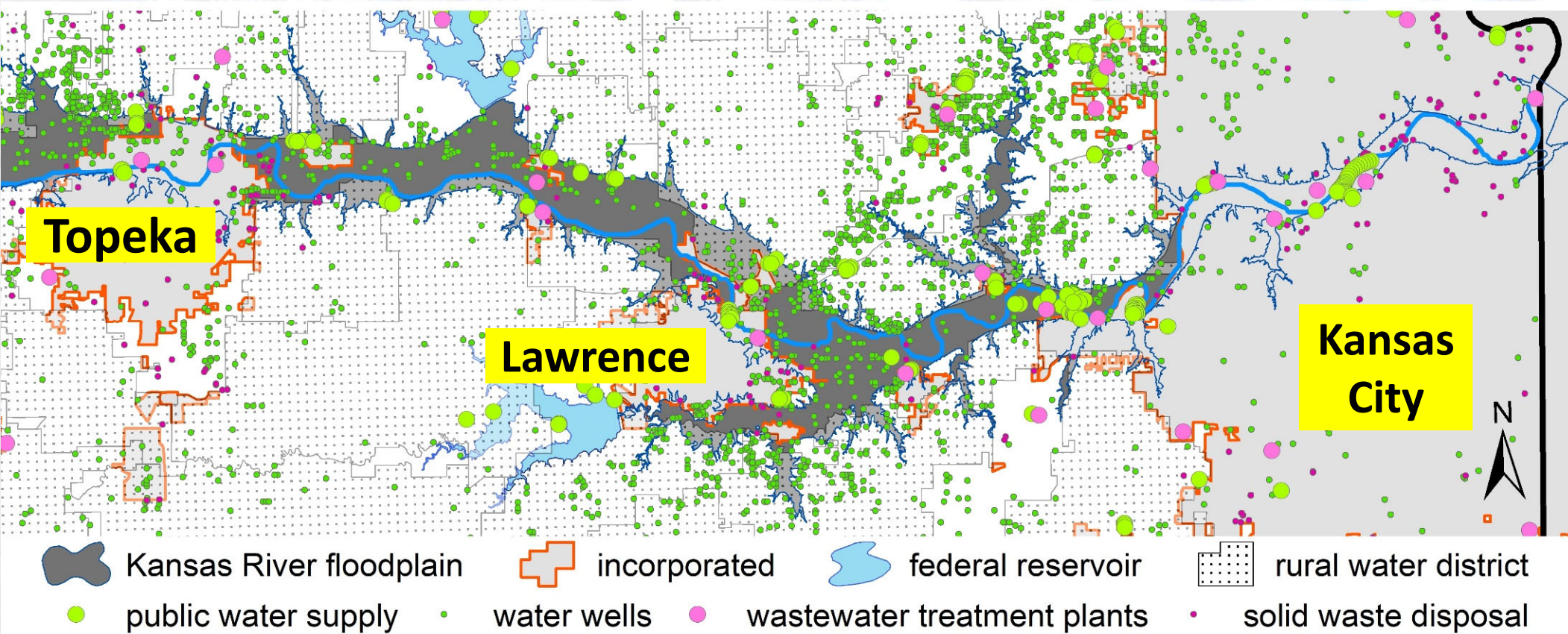
Kansas Model (NWM calibrated)



Exploration of National Water Model (NWM) output for operational use in Kansas is underway

Highlighting Water Infrastructure Impacts

A sample of water infrastructure in the Kansas River floodplain



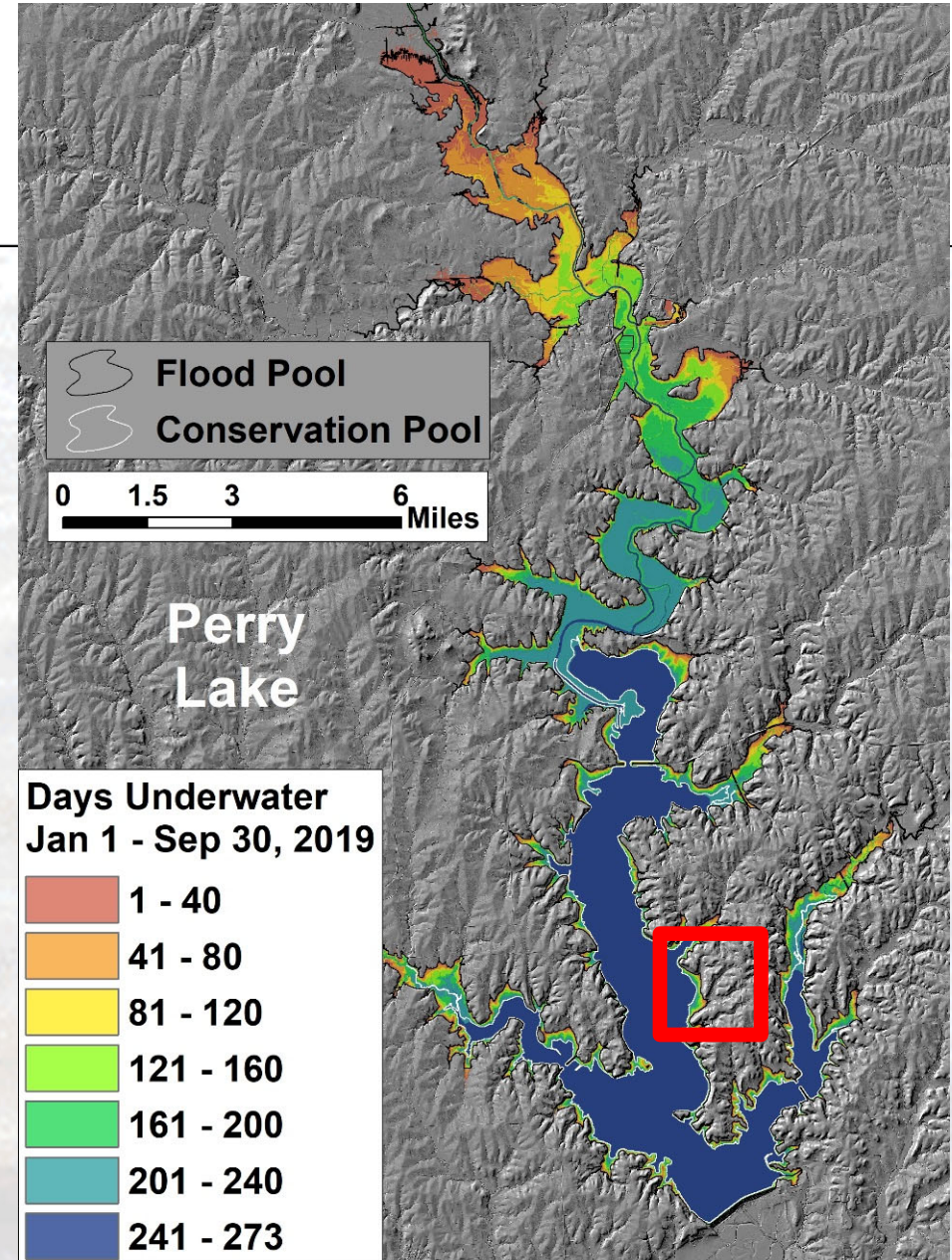
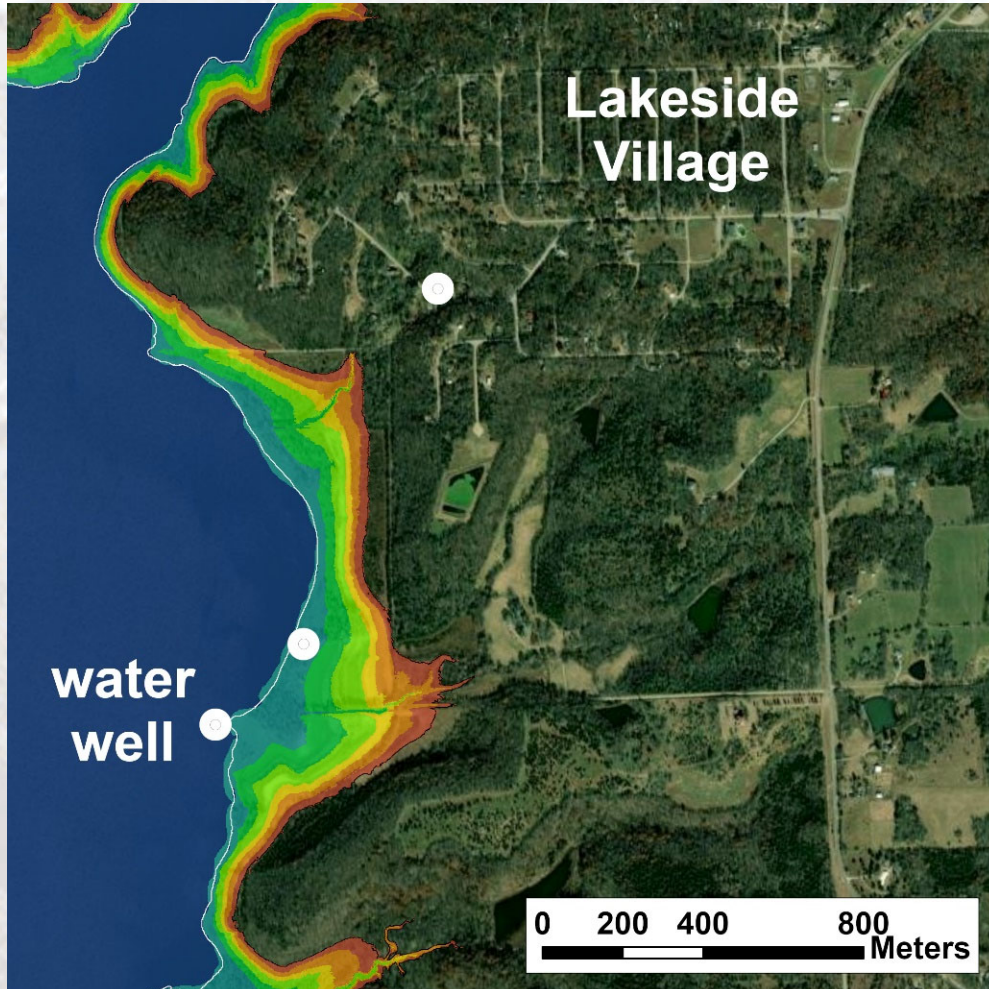
Flood Impacts: Public Water Wells

Guard still hauling water to residents near Perry Lake



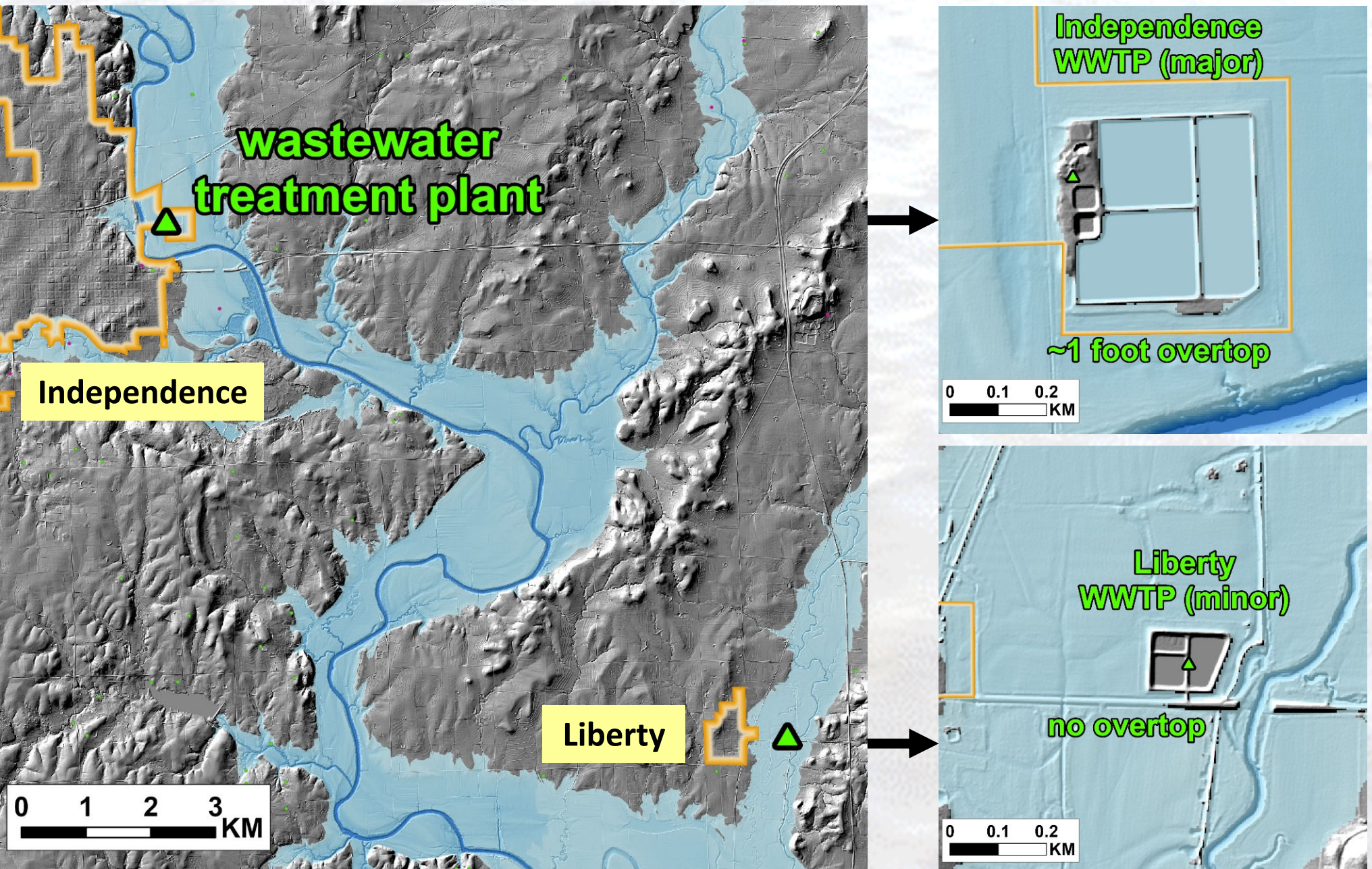
By Associated Press Thursday, July 25, 2019

2 months
after flood



Flood Impacts: Wastewater Treatment Plants

Simulation of peak 2019 flooding along the Verdigris River in Montgomery County, Kansas



Examples of Other Floodplain Assets that Could Pose a Risk to Water Quality During Extreme Flooding

- Industrial hazardous waste holdings**
- Landfills**
- Manure lagoons**

With geospatial inventory for such features integrated into the mapping tools, flood forecasts could provide early warning & help assess impacts.

Thanks for Listening...

Any Questions?



Jude Kastens
jkastens@ku.edu