Attenuation of Flood Risk in the Missouri River Floodplain

CHARACTERIZING PROSPECTS FOR WETLAND ESTABLISHMENT

Mohammad Jaweed Nazary, Ph.D. Candidate

Kathleen M. Trauth, Ph.D., P.E., Principal Investigator

University of Missouri

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Background

EPA Research Grant

Attenuation of Flood Risk in the Missouri River Floodplain: Characterizing Prospects for Strategic Wetland Establishment

Strategic wetland restoration within floodplains is a proven mechanism for attenuating flood risk

Modifying levee systems could potentially restore the ecological and economic benefits currently lost

The crucial first step is accurately mapping the existing levee infrastructure

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The Problem

DO WE KNOW WHERE ALL THE LEVEES ARE?

"There are an unknown number of levees in the U.S. that have yet to be identified or inventoried"

(USACE's Levee Safety Program, 2018, p1)

"Current estimates identify up to 10,000 additional miles of levees outside of the U.S. Army Corps of Engineers (USACE) portfolio whose location and condition are unknown due to complex and varying local ownership"

(ASCE Infrastructure Report Card, 2021, p71)

"There may be as many as 100,000 miles of nonfederal levees in the United States."

(Carter & Horn, CRS Report, 2023, p1)

A PYTHON PACKAGE

Mizzou Floodplain Characterization

- ❑ Streamlines Multi-Agency Data Processing
- ❑ Works Directly on the LiDAR* Point Cloud
- ❑ Includes a Levee Identification and Mapping Tool
- ❑ Includes a Channel Identification and Mapping Tool
- ❑ Includes an Editable Multi-Objective Suitability Analyses Framework

* LiDAR: Light Detection And Ranging

```
pip install Mizzou-Floodplain-Characterization==0.1.0
```

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JUPYTER NOTEBOOKS

Five Notebooks to Perform all the Calculations

I. Downloading and Processing Digital Elevation Model (DEM)

II. Downloading and Processing Multi-Agency Data

III. Downloading and Processing LiDAR Data

IV. Tracing of Floodplain Features

V. Performance of Suitability Analysis

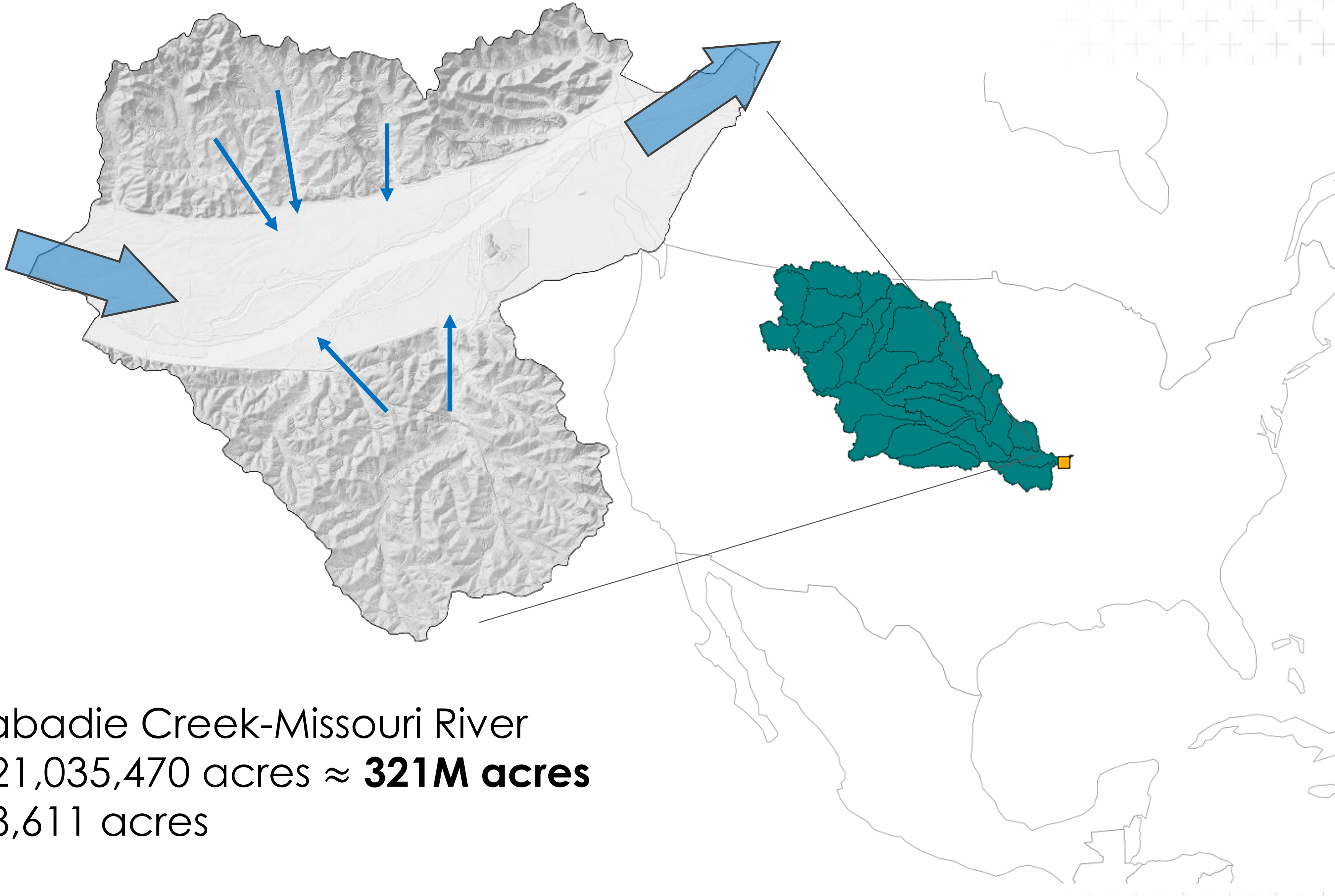
JUPYTER NOTEBOOKS

Five Notebooks to Perform all the Calculations

- ❑ Accepts Hydrologic Unit Code 12 (HUC12) Watersheds as Input
- ❑ Provides a Step-by-Step Methodology
- ❑ Allows for an Editable Workflow
- ❑ Utilizes LiDAR Processing Codes Optimized for both CPUs (Conventional Computers) and GPUs (Graphical Processing Units)

Example Site

HUC12 = 03002000603

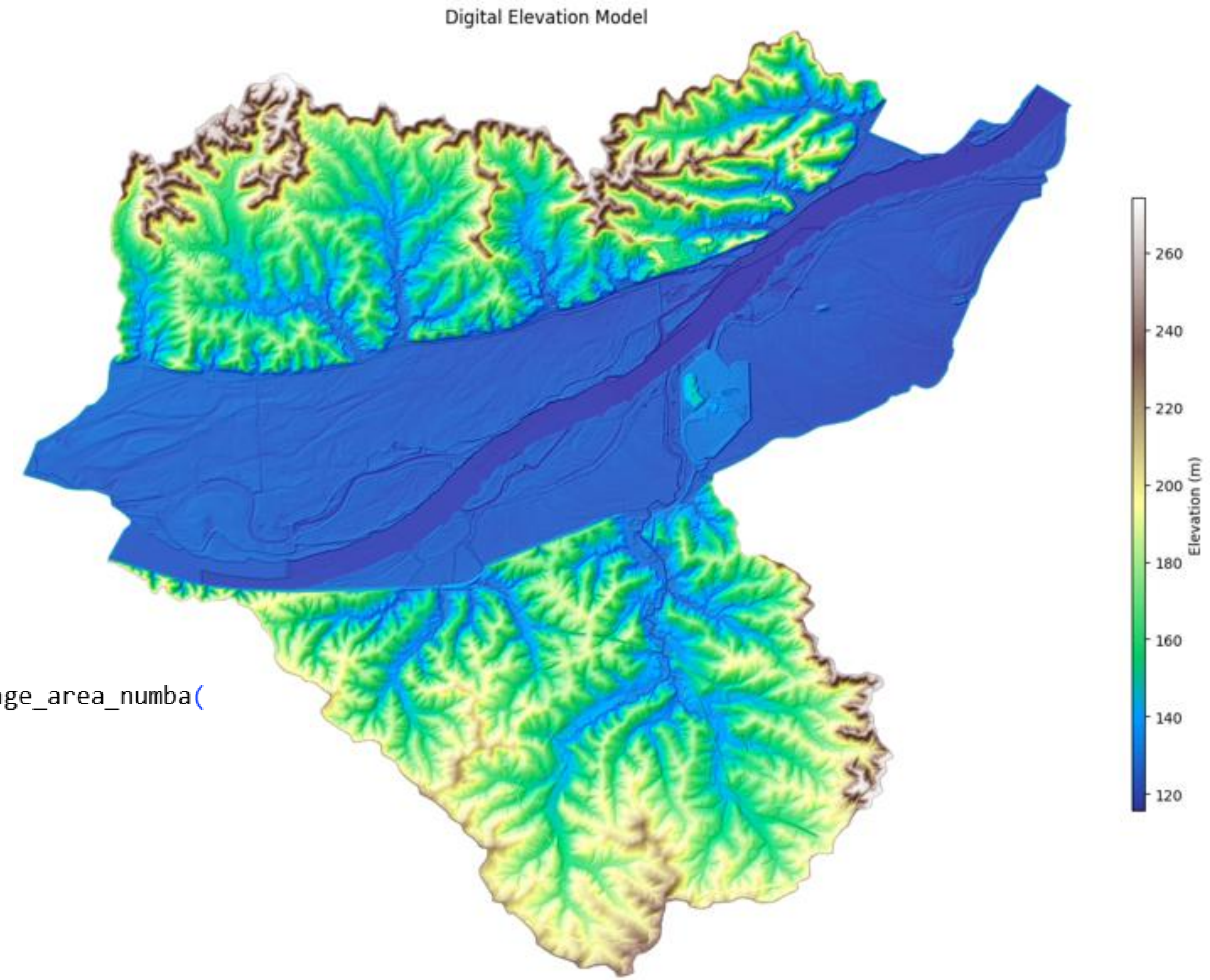


Watershed Name = Labadie Creek-Missouri River
Upstream Area = 321,035,470 acres ≈ **321M acres**
Watershed Area = 38,611 acres

DEM Processing

USGS 3DEP DEM

- Flow Direction
- Flow Contributing Area
- Height Above the Nearest Hydrological Drainage
- Contributing Area of the Nearest Hydrological Drainage

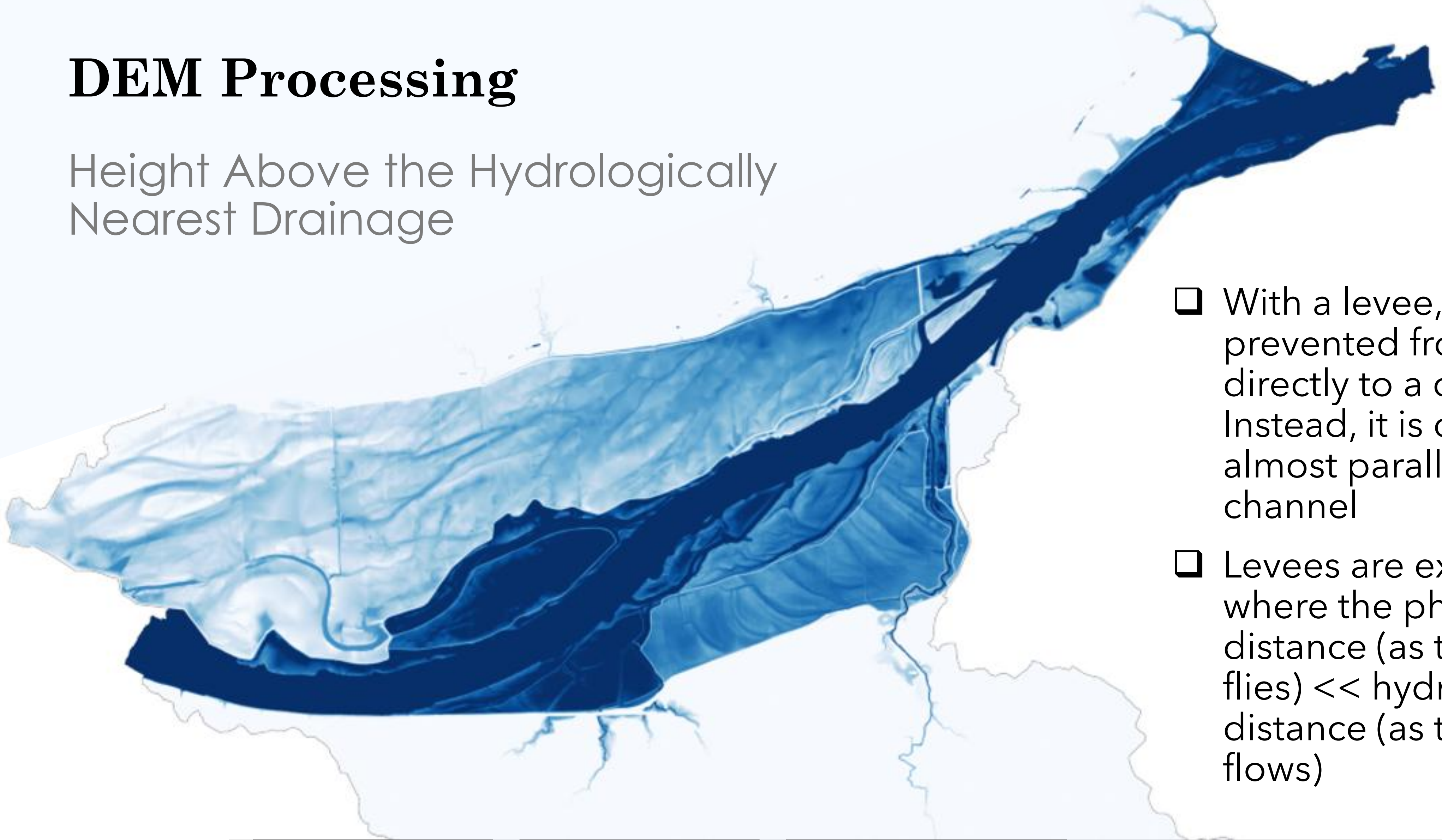



```
Ac, flow_dist, (out_r, out_c) = flow_distance_nearest_drainage_area_numba(
    flowdir= fd,
    flowacc= fa,
    drainage_mask= fa> 50000,
    cellsize_x = 5.0,
    cellsize_y = 5.0,
    flowacc_is_cellcount = True,
    nodata_flowdir=0,
    nodata_flowacc=np.nan)
```

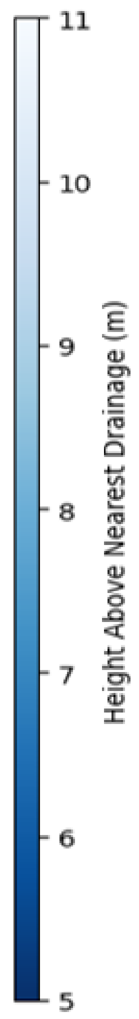
```
Assigning nearest drainage and computing flow distances...
Computing HAND...
Elapsed time = 0.79 sec.
```

DEM Processing

Height Above the Hydrologically Nearest Drainage



- With a levee, water is prevented from flowin directly to a channel. Instead, it is directed almost parallel to channel
- Levees are expected where the physical distance (as the crow flies) << hydrological distance (as the water flows)



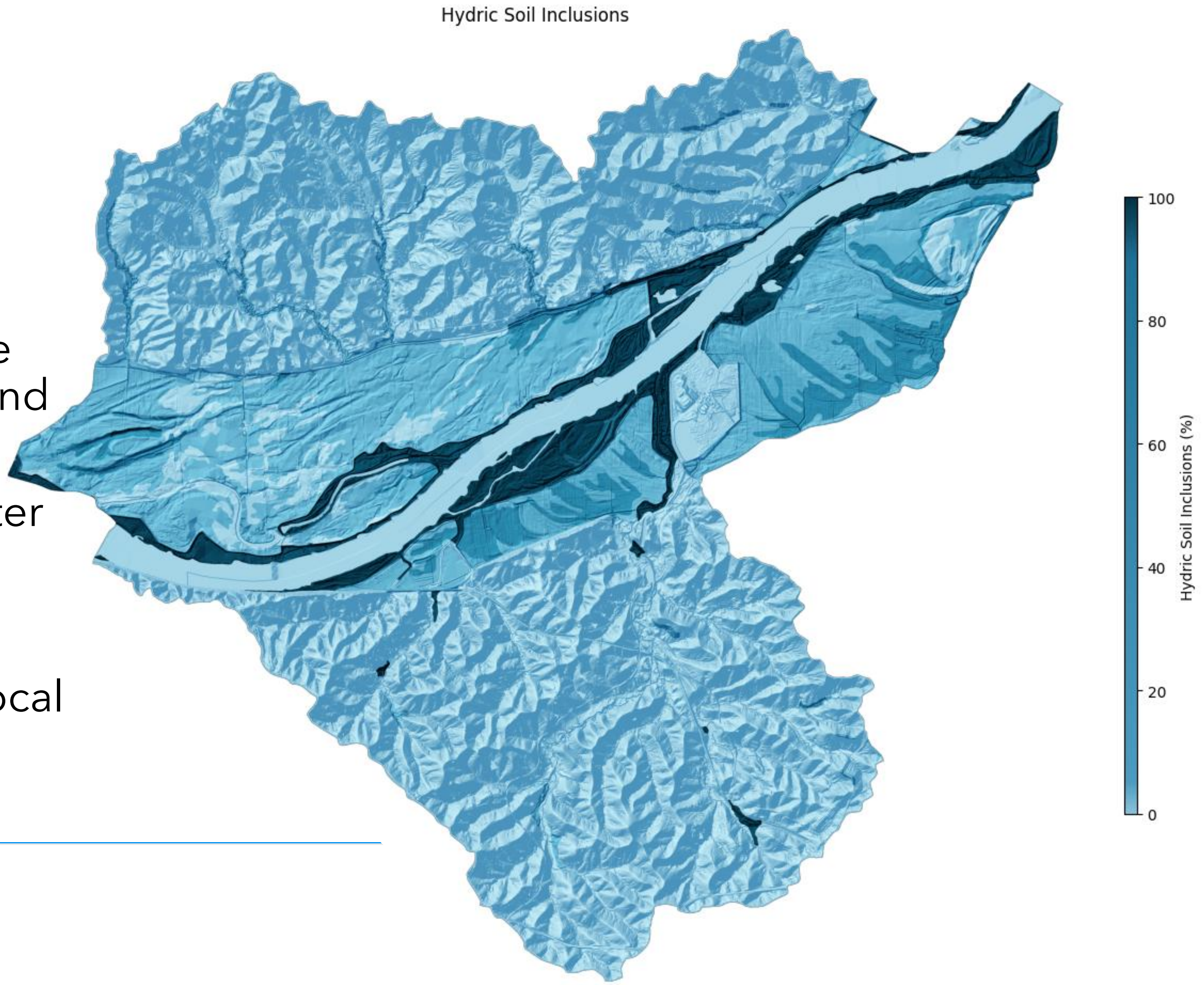
Multi-Agency Data

HYDRIC SOIL INCLUSIONS

- ❑ Hydric soil inclusions suggest the area may naturally support wetland functions
- ❑ Converts data from vector to raster
- ❑ Reprojects data to a consistent coordinate system
- ❑ Saves this GEOTIFF data into a local directory on the user's computer

```
1 fc = download_SSURGO(geom.wkt)
```

```
Retreiving hydric soil data...
Polygons: 895
379340015 2532900 0.0
379340035 2534716 0.0
379340225 2532886 0.0
379340227 2532870 0.0
379340262 2498831 0.0
```



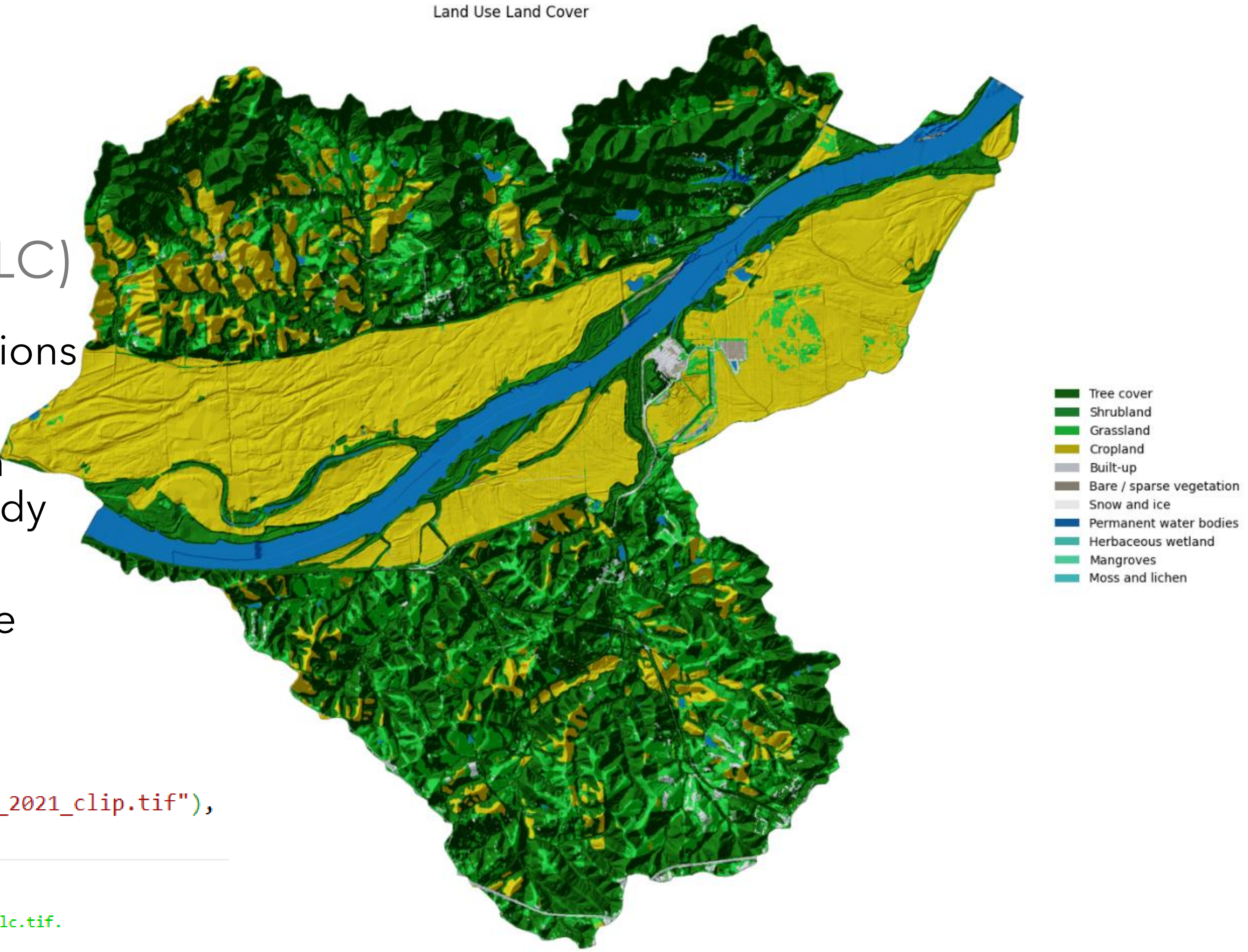
Multi-Agency Data

LAND USE LAND COVER (LULC)

- LULC indicates how land conditions impact runoff
- Land Use represents restoration constraints (where there is already development)
- Processing is the same as before

```
out = download_LULC(
    aoi_geom=geom,
    aoi_crs_epsg=4326,
    req=LULCRequest(year=2021, out_tif="worldcover_2021_clip.tif"),
)
```

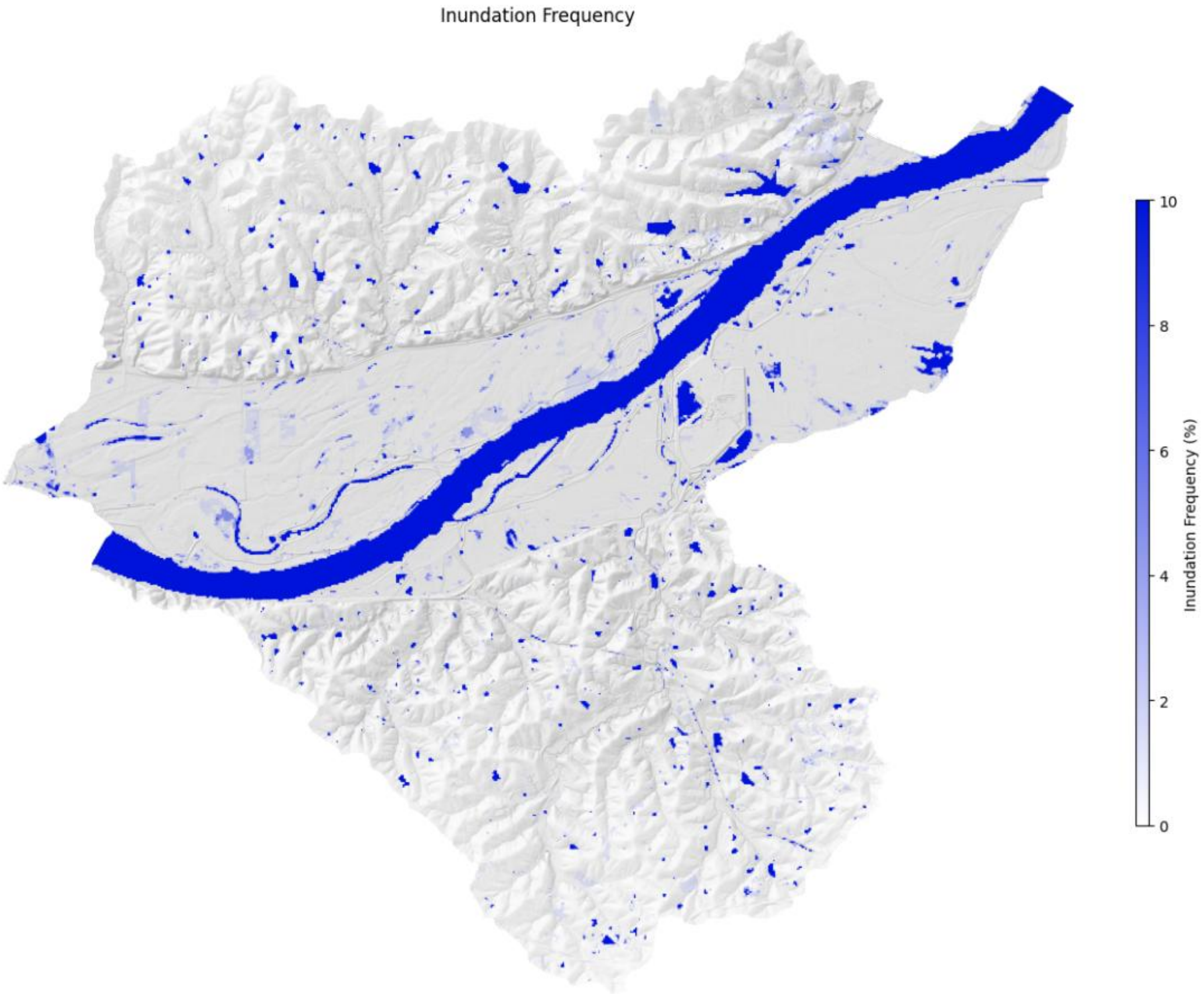
```
Retreiving Land Use Land Cover Data...
Reprojecting to dataset standard porjection...
LULC was successfully saved at/content/drive/MyDrive/Suitability_Project as lulc.tif.
Ploting LULC...
```



Multi-Agency Data

NASA OPERA*

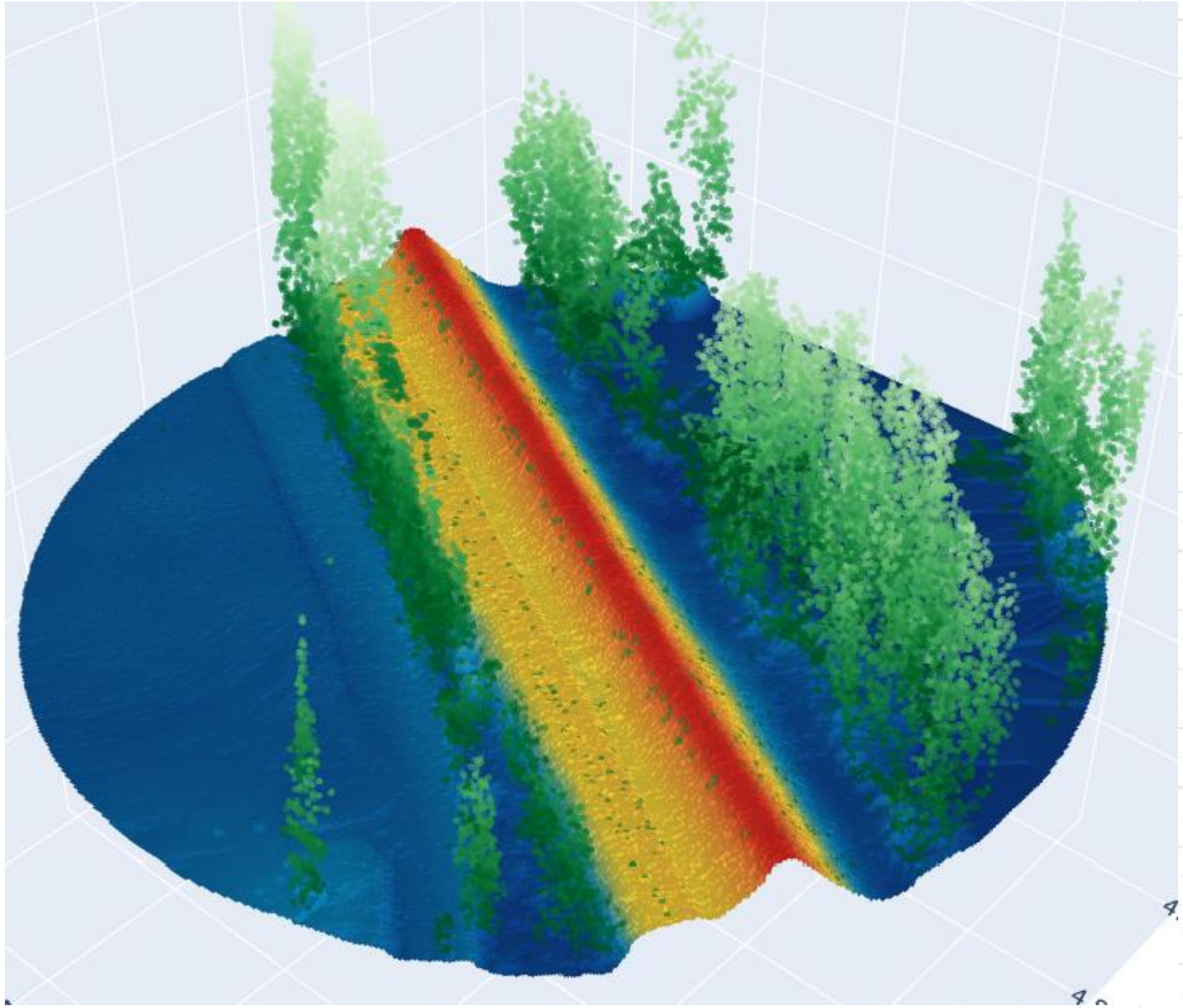
- ❑ Observation of frequently inundated areas for a given time period
- ❑ Inundation frequency is an indicator of potential suitability for wetland restoration
- ❑ Processing is the same as before
- ❑ Additional processing computes the probability of inundation



LiDAR Data

USGS 3D Elevation Program

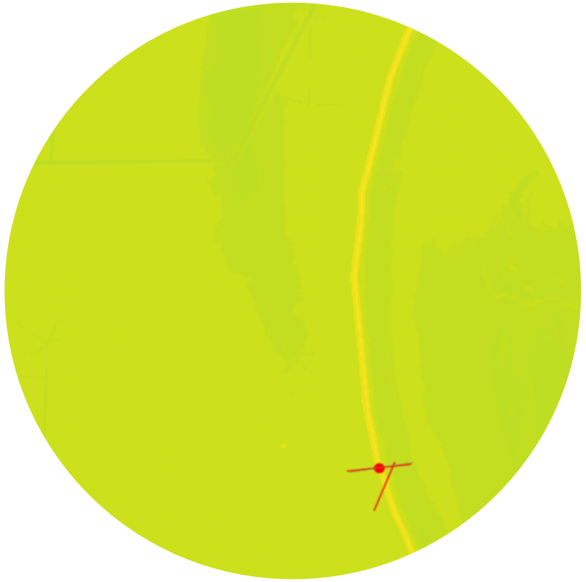
- LiDAR captures the fine-scale landscape features
- Preserves original 3D observations
- Small features may not be distinguished on a DEM, specifically in highly vegetated areas.
- A code written for this project downloads the point cloud data for a given site

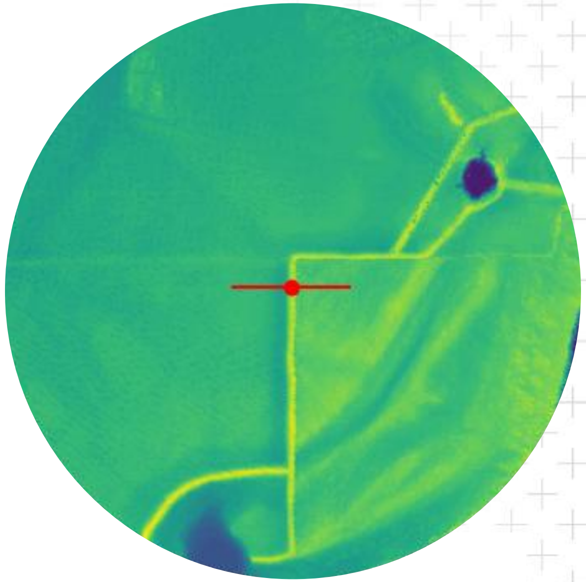


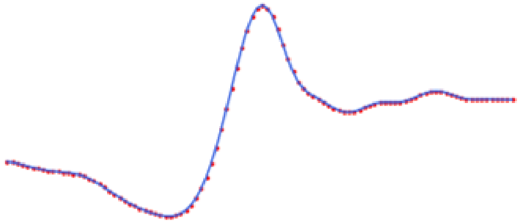
Levees and Channels

CODES

- ❑ Identifies the location of the levee and levee-like features
- ❑ Identifies the location of active and paleo channels
- ❑ Performs orientation estimation
- ❑ Traces levees and channels along their length







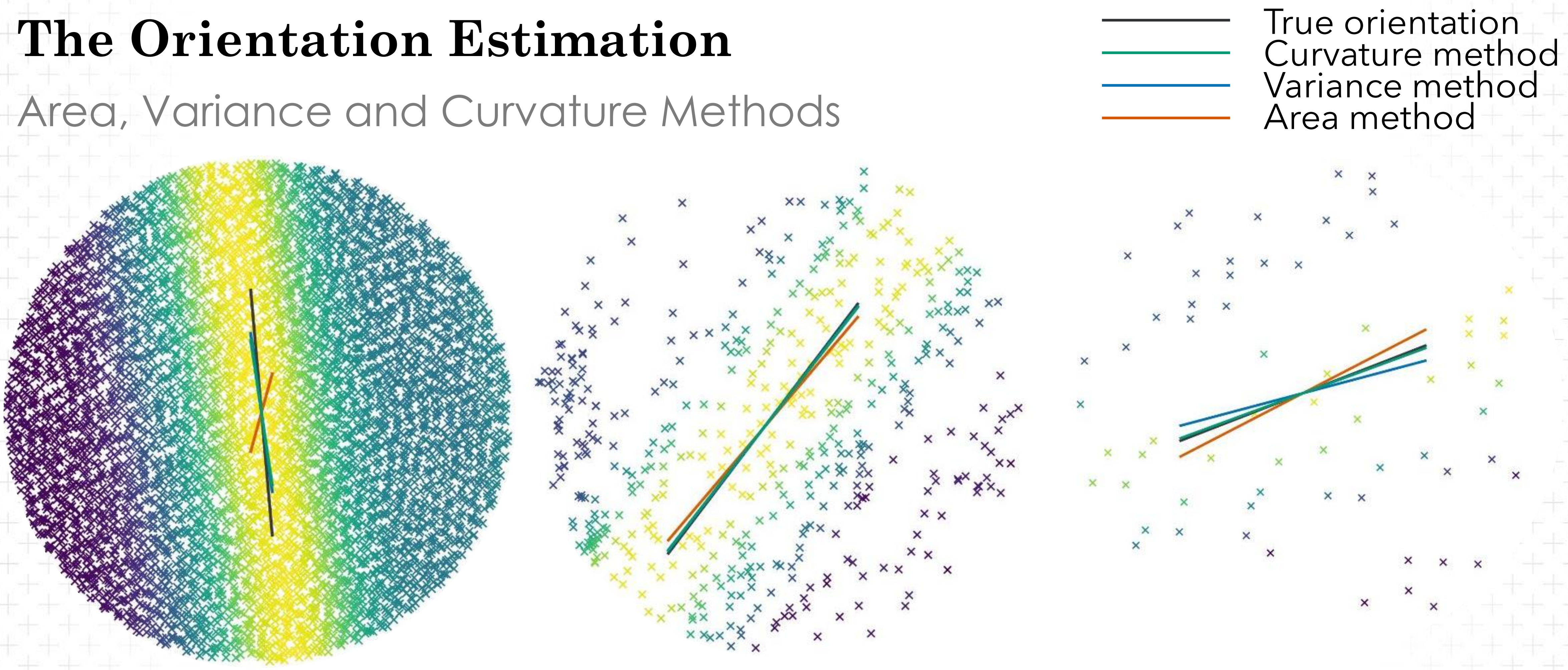
Identification of the location of levees and channels

The Crawl Method

- A sufficiently large number of random locations are selected
- The code climbs uphill from those locations until arriving at high points as levee crests
- The code descends downhill from those locations until arriving at low points as channel thalwegs (opposite of a crest)
- Levees and channels are identified based on the geometric characteristics of the estimated landscape surface at the final crawled location as well as subsequent traced locations.

The Orientation Estimation

Area, Variance and Curvature Methods



Densely Sampled Levee

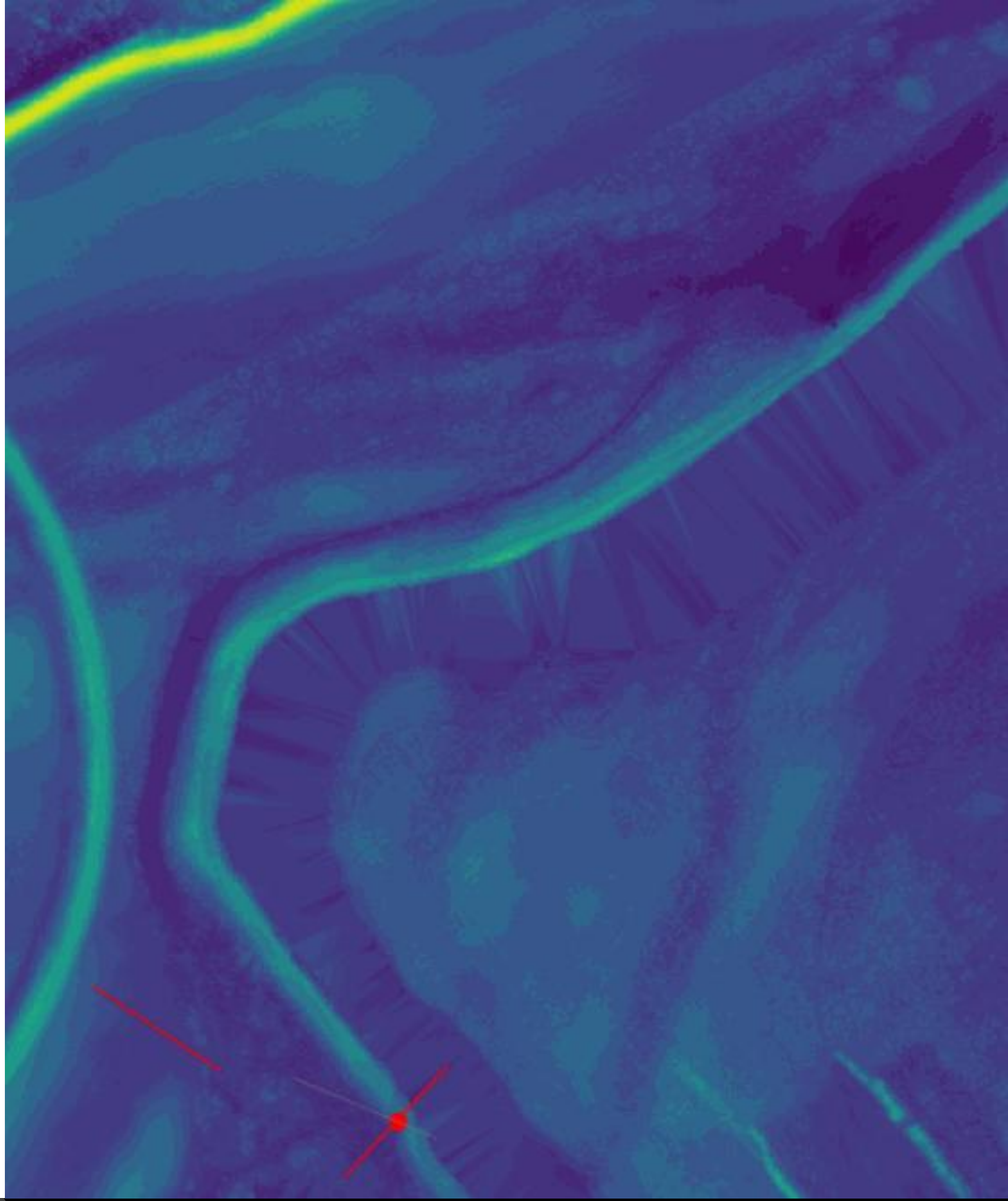
Poorly Sampled Levee

Very Poorly Sampled Levee

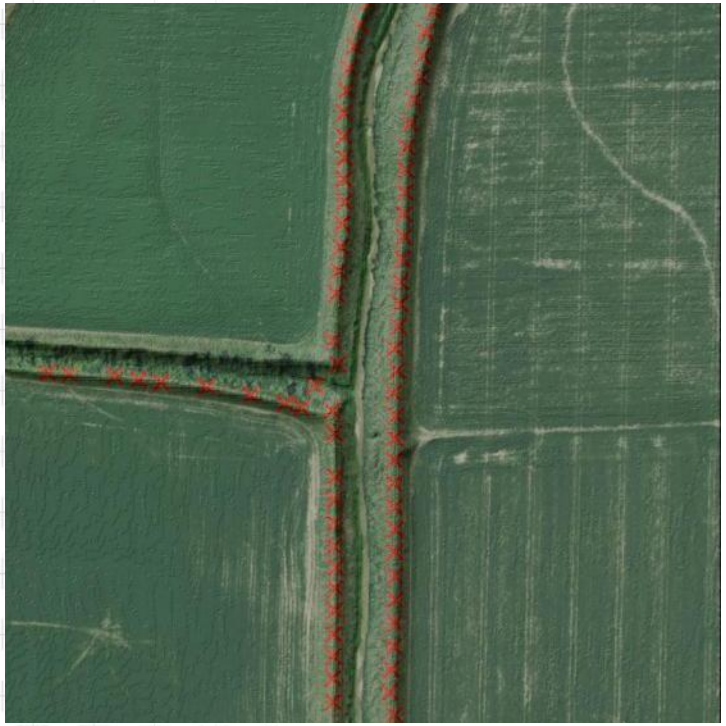
Tracing levees and channels

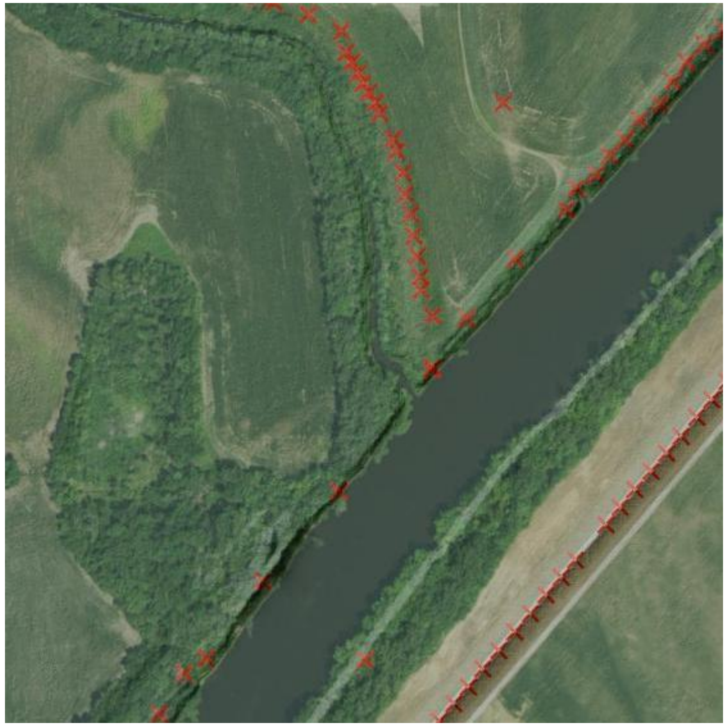
The Trace Method

- For a given crest or thalweg location, a step is taken along the estimated direction feature
- Underlying geometric characteristics are estimated at new arrival location
- If the offset is not centered on the centerline of the feature the Crawl is used again to find the centerline
- This process is repeated as long as the underlying geometry resembles targeted feature geometry

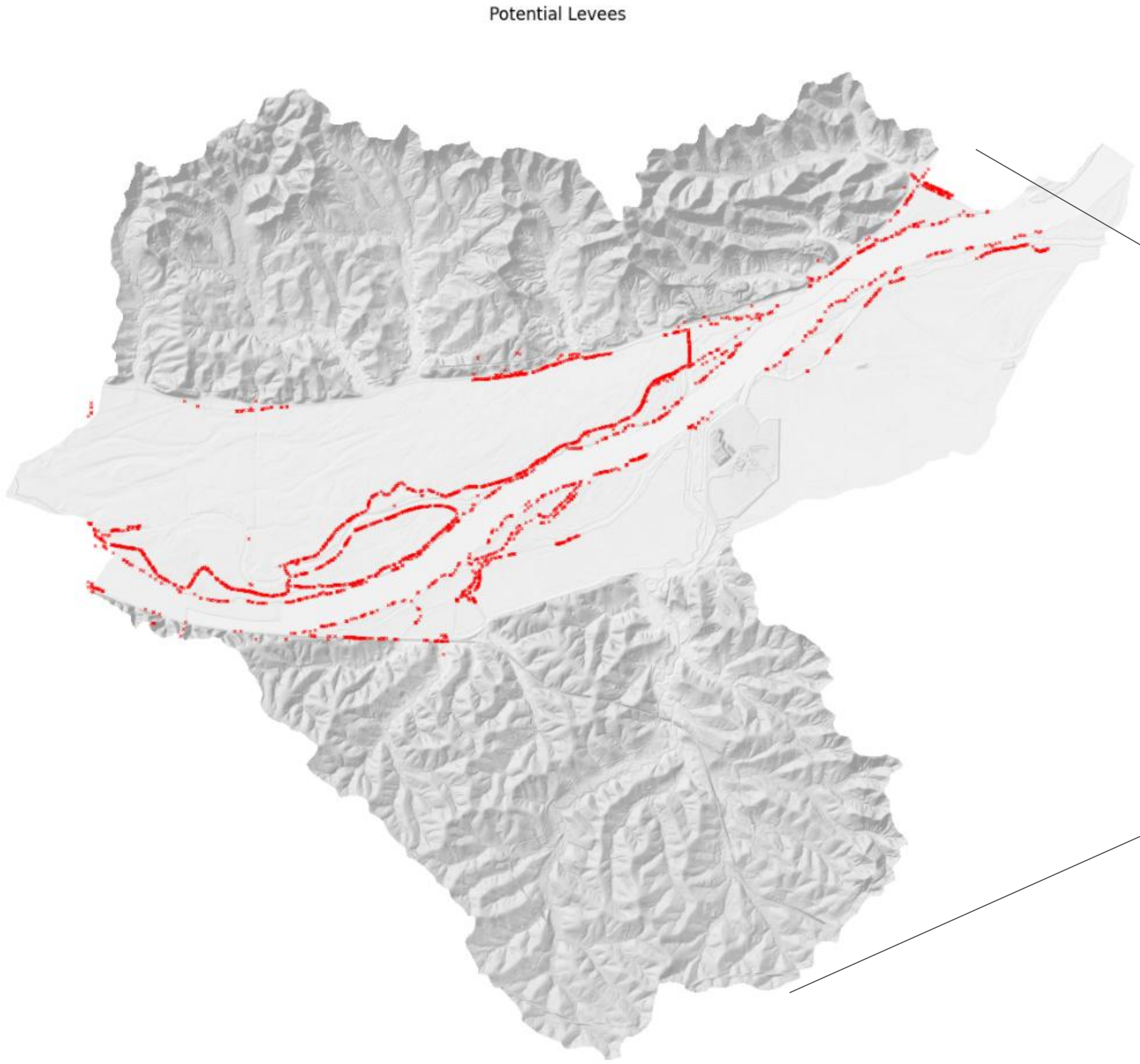


Example Cases of Levee Tracing





Example Cases of Channel and Old Channel Tracing



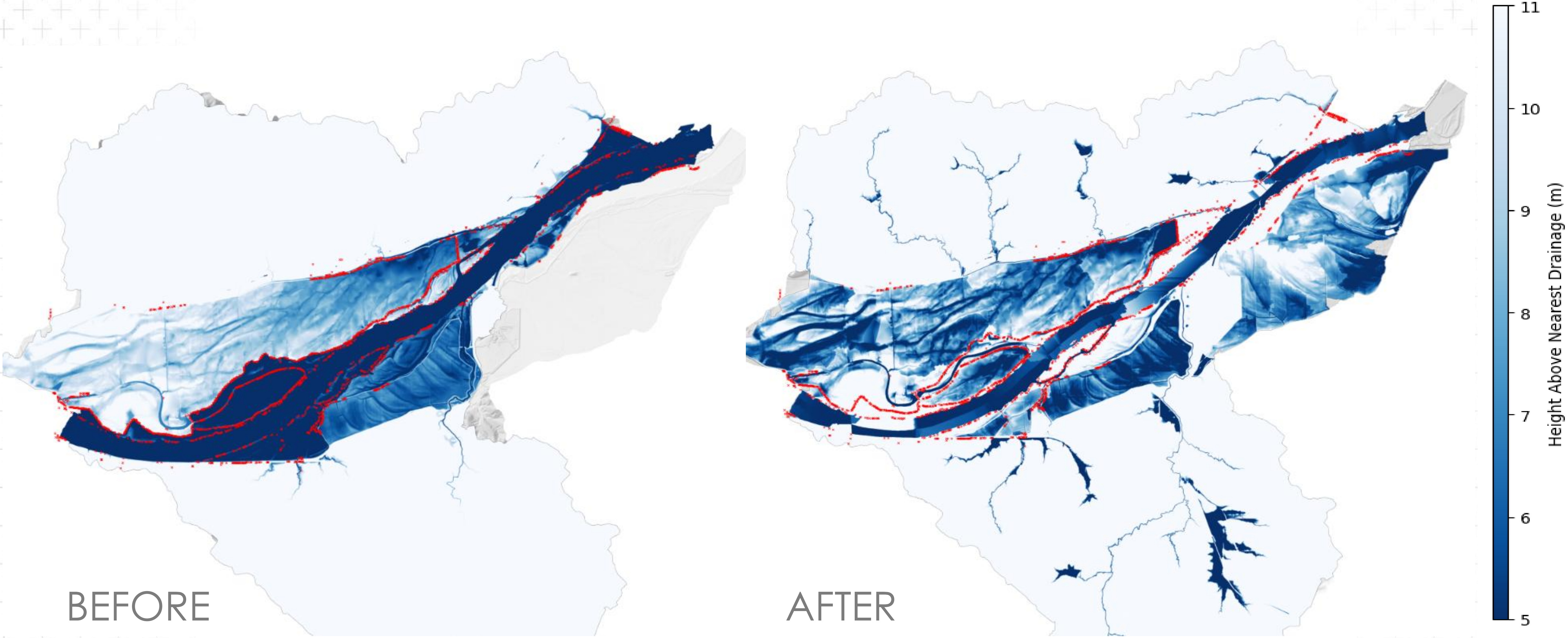
Levees found within the example site

HUC12 = 03002000603

Analysis of Levee Removal

- Allows for a better hydrologic assessment of leveed areas where conventional DEM processing often artificially fills low areas
- Allows the hydrological distance from a location to its nearest channel to be more representative of the natural landscape before levee construction

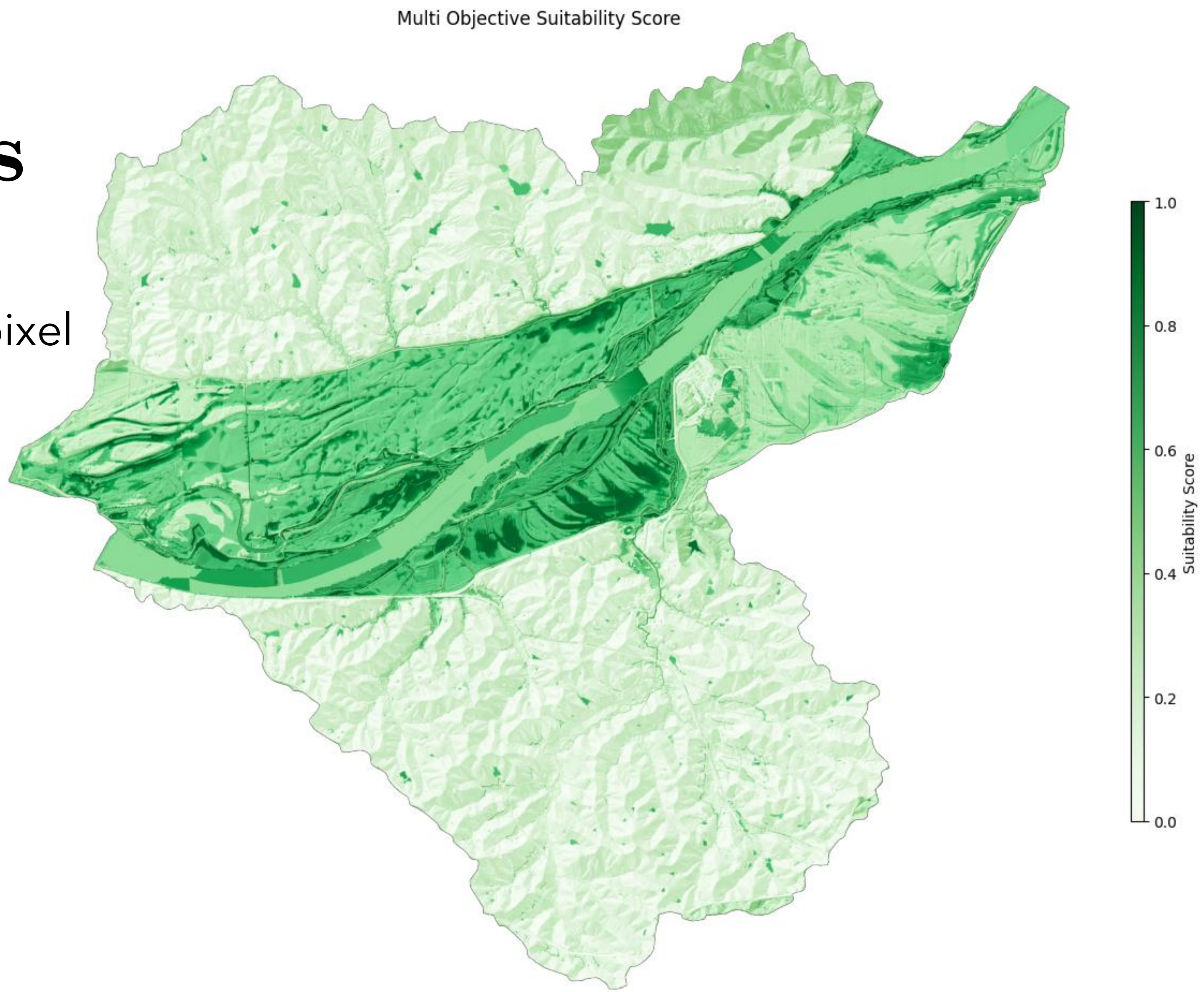
Analysis of Levee Removal



Suitability Analysis

MULTI-OBJECTIVE

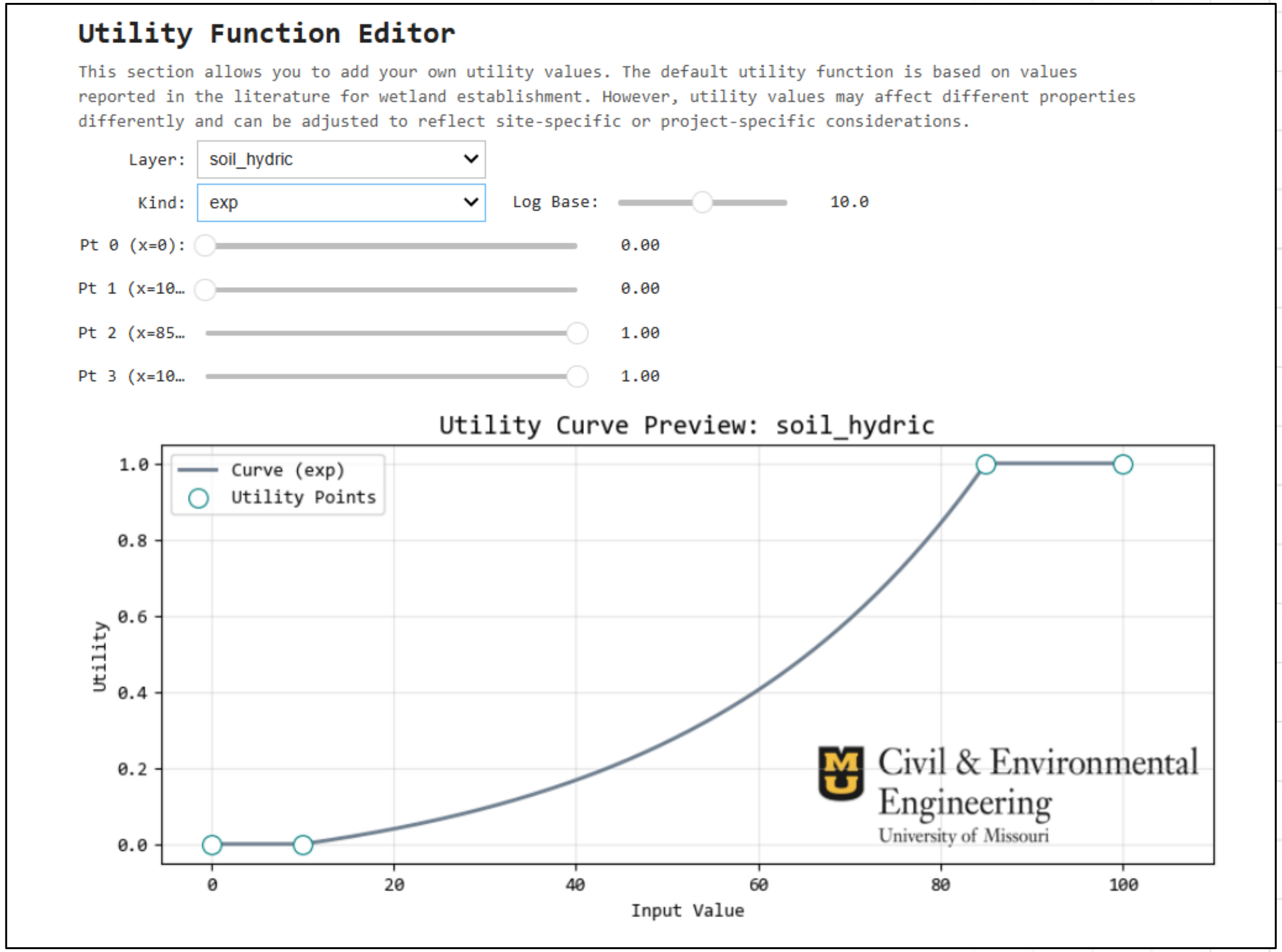
- ❑ Have the value of each layer at every pixel
  - ❑ Hydric soil inclusion
  - ❑ Land use land cover
  - ❑ Storage capacity
  - ❑ Slope
  - ❑ Height above the nearest drainage
  - ❑ Inundation frequency
- ❑ Normalize values for each layer (0-1 according to their application to the objective)
- ❑ Normalization relationships are not necessarily linear. The code allows for introducing non-linear relationships



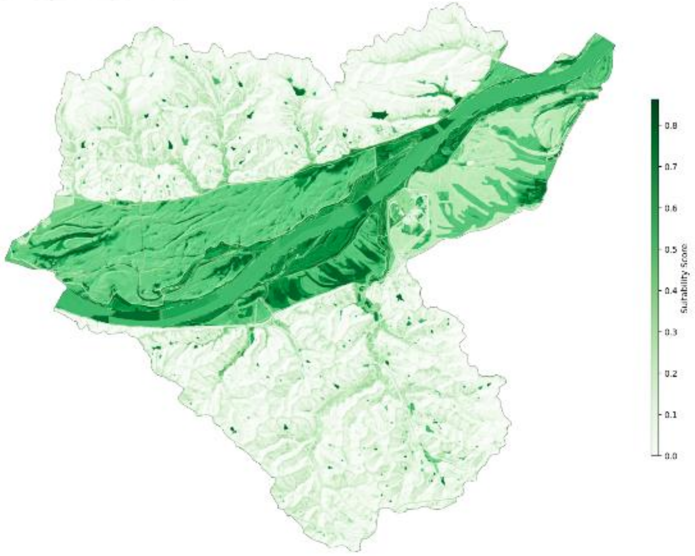
Suitability Analysis

MULTI-OBJECTIVE

- ❑ Interactive utility editor allows the user to change the relationships between each layer and the objective
- ❑ The importance of each layer is then defined by assigning a weighting factor based on the objective
- ❑ The weighted sum is calculated as the suitability index for an objective
- ❑ Tradeoff analysis is performed to assess competing objectives



Objective 1

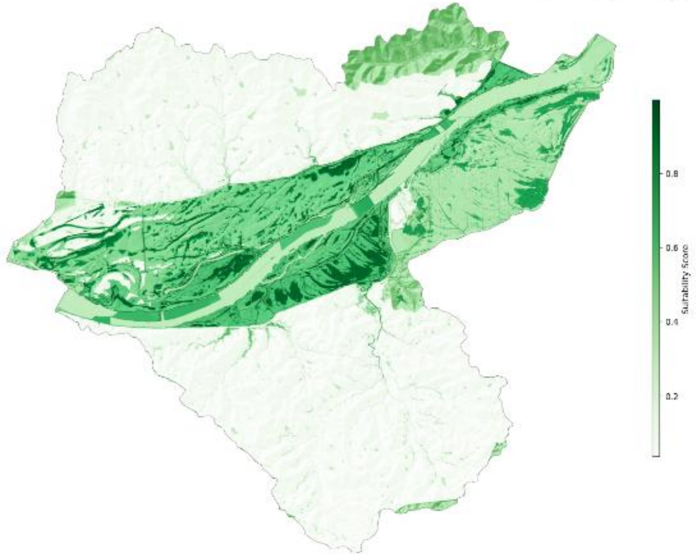


Wetland Restoration

Objective 2

Local Flood Risk Mitigation

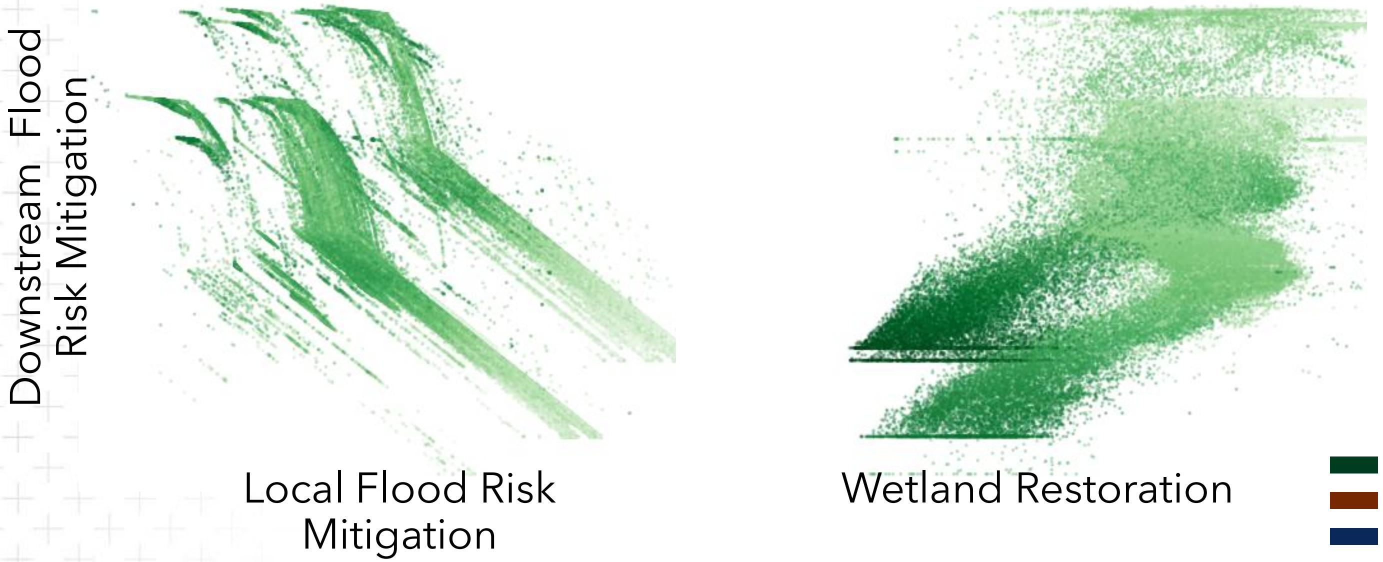
Objective 3

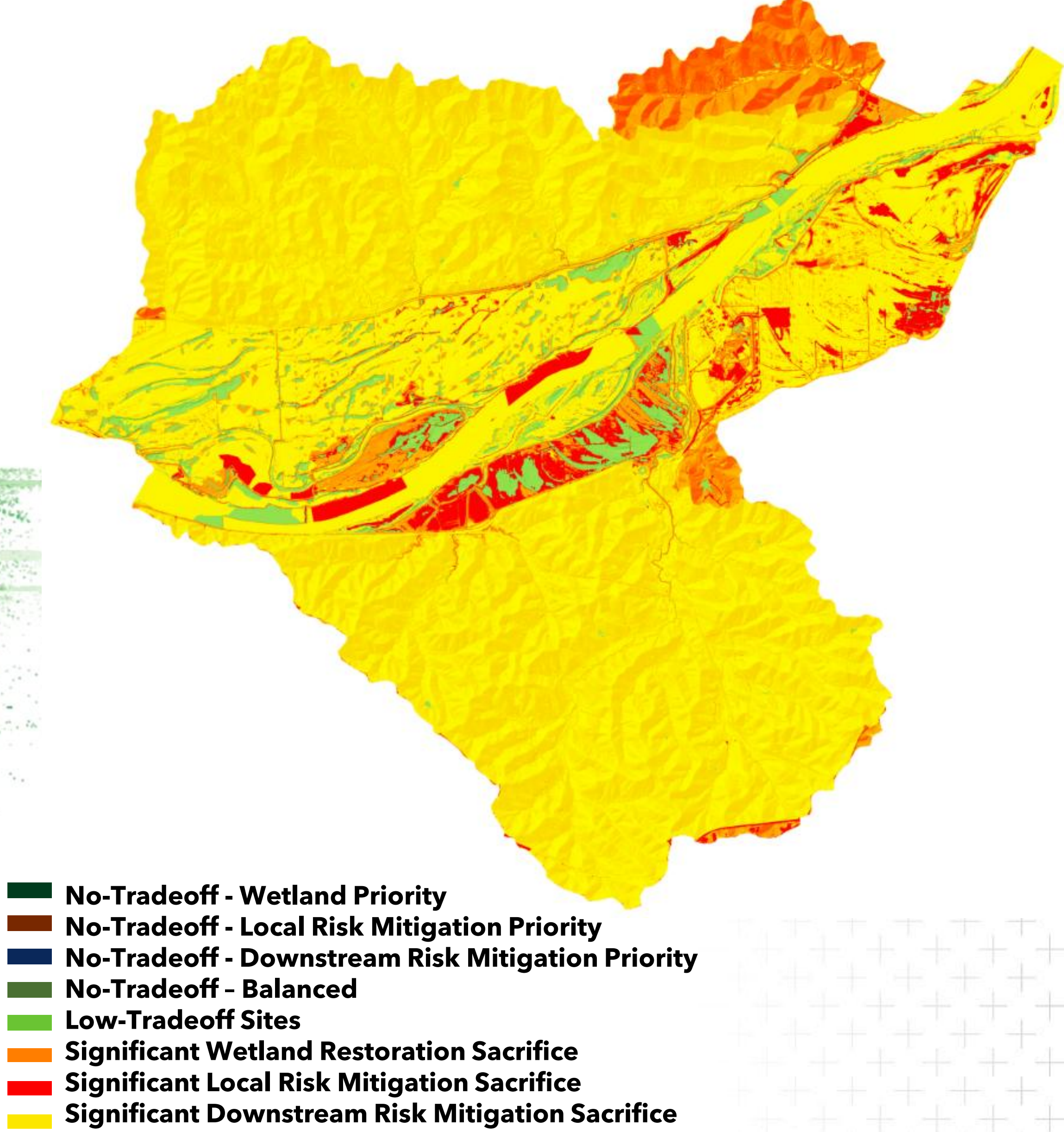


Downstream Flood Risk Mitigation

Tradeoff Analysis

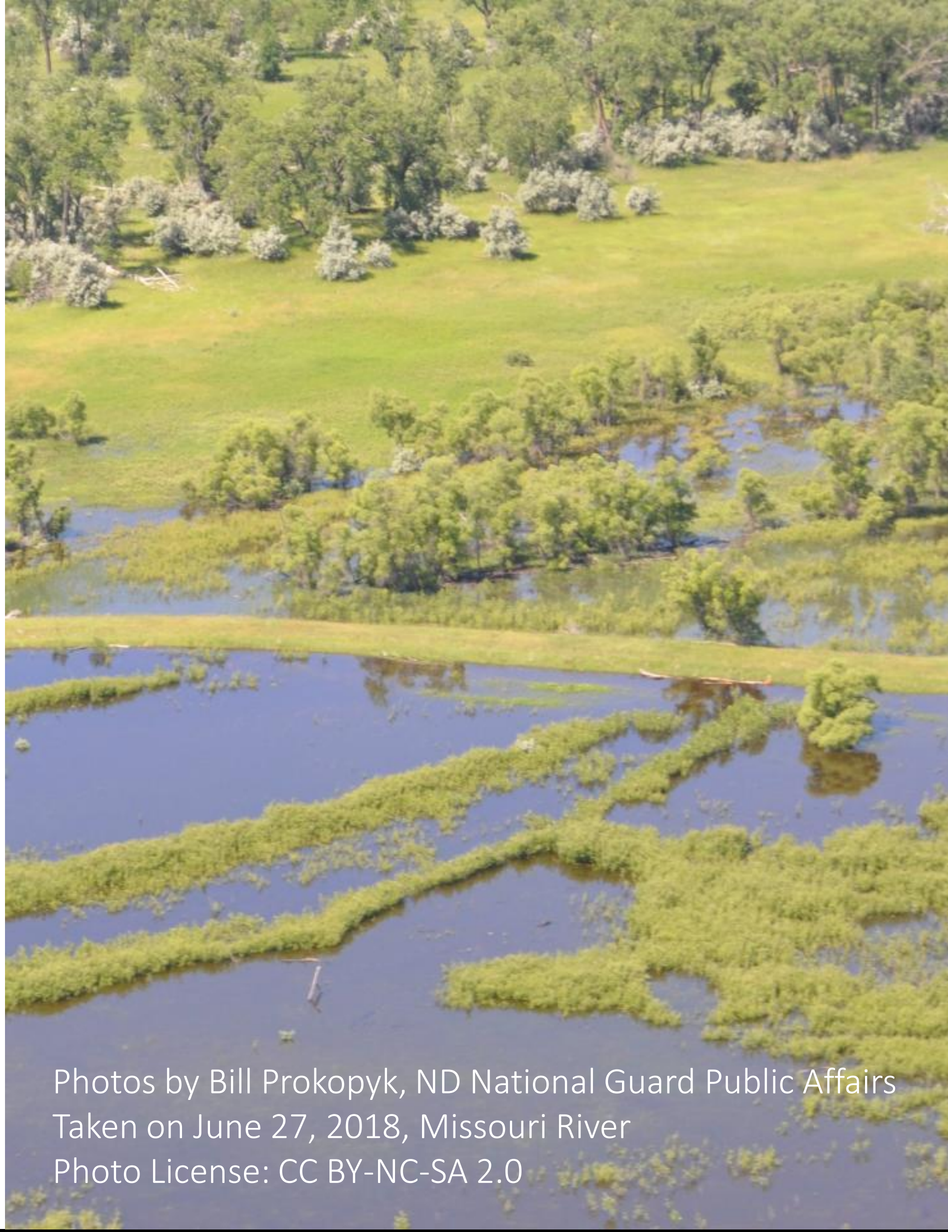
COMPETING OBJECTIVES





Conclusions

- ❑ Methodologies and python implementation codes were developed to identify levees and channels
- ❑ Methodologies and python implementation codes were developed for suitability analyses and informed decision-making
- ❑ The methodologies have been tested against a diverse array of watersheds from a real-world dataset
- ❑ Five computational notebooks are provided to run the codes introduced here
- ❑ The notebooks can be run on a personal laptop
- ❑ Instructions are provided for all the codes in a step-by-step manner



Photos by Bill Prokopyk, ND National Guard Public Affairs
Taken on June 27, 2018, Missouri River

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Any Questions?