Using LiDAR to map sinkholes in Jefferson County, West Virginia

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"Geohazards in Transportation in the Appalachian Region"

Project Objectives

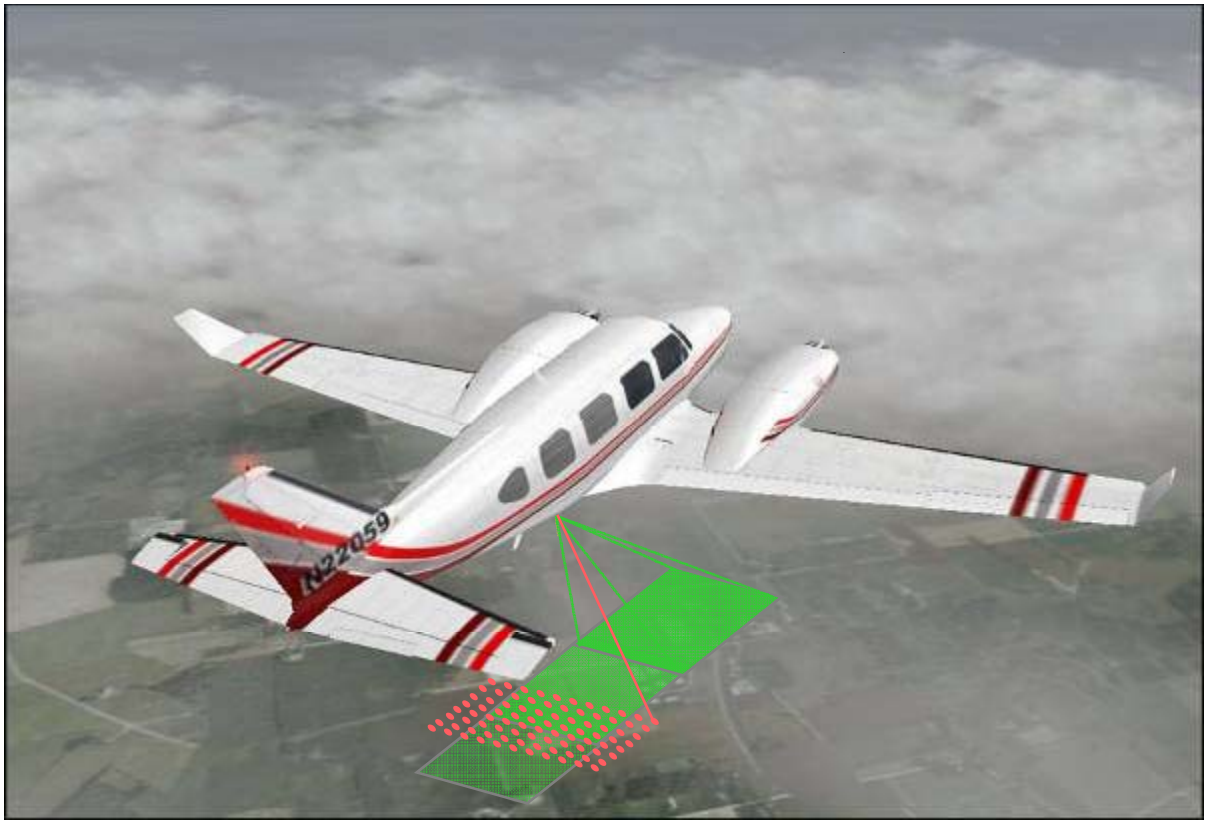
* In support of USGS study of water availability and threats to water supply of Leetown Science Center (Kozar et al.)

1. Acquire LiDAR data to allow for modeling of fine scale surface features
2. Generate fine-scale digital elevation models from LiDAR data
3. Use topographic analysis, aerial photography, and statistical analysis to map sink holes and potential groundwater recharge zones from fine-scale surface models

What is LiDAR?

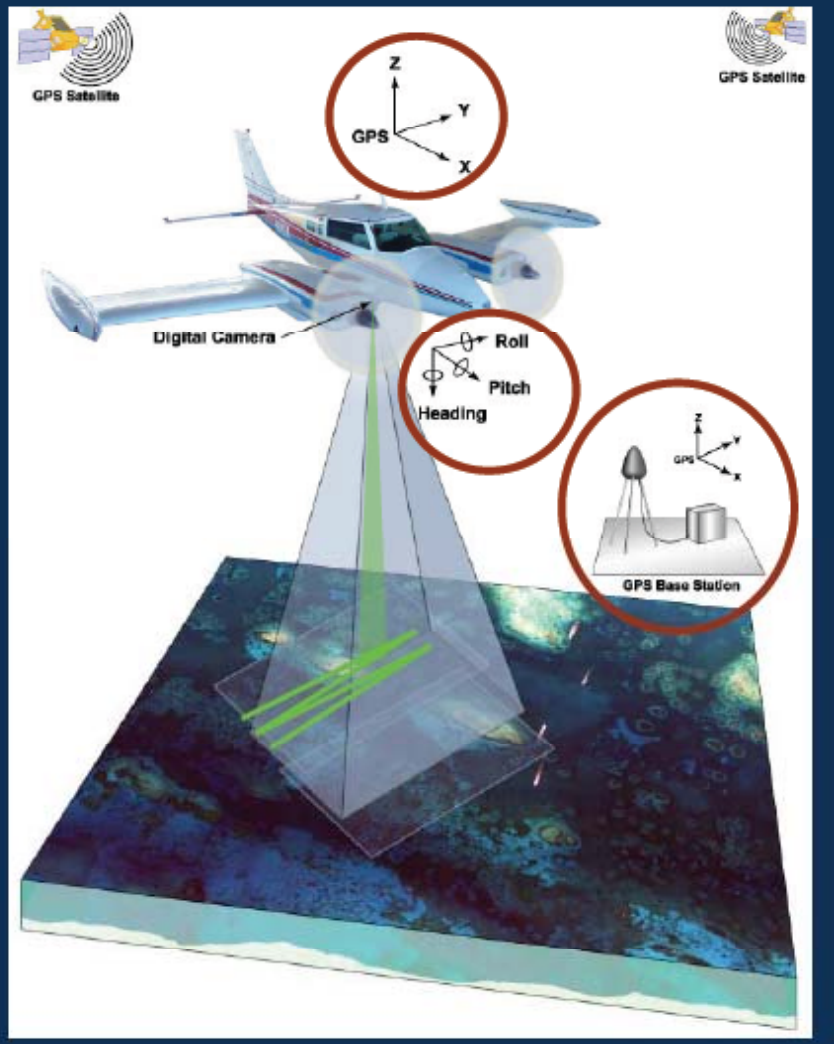
- LiDAR = Light Detection And Ranging (aka "airborne laser scanning")
- Laser pulses sent from aircraft in dense scanning pattern (0.5-2 meters apart)
- Return of laser pulse recorded at aircraft
- Time to return, speed of light, and altitude of plane used to compute surface height (z) of each pulse with high accuracy
- Ground position of each laser pulse computed using differential GPS (x,y)

What is LiDAR?



Lidar System Components

- Lidar Transmitter, Scanner, and Receiver
- Aircraft Positioning – Differential GPS (with post-processing)
- Aircraft Attitude – Pitch, Roll, Yaw – Inertial Navigation System (GPS-Aided)



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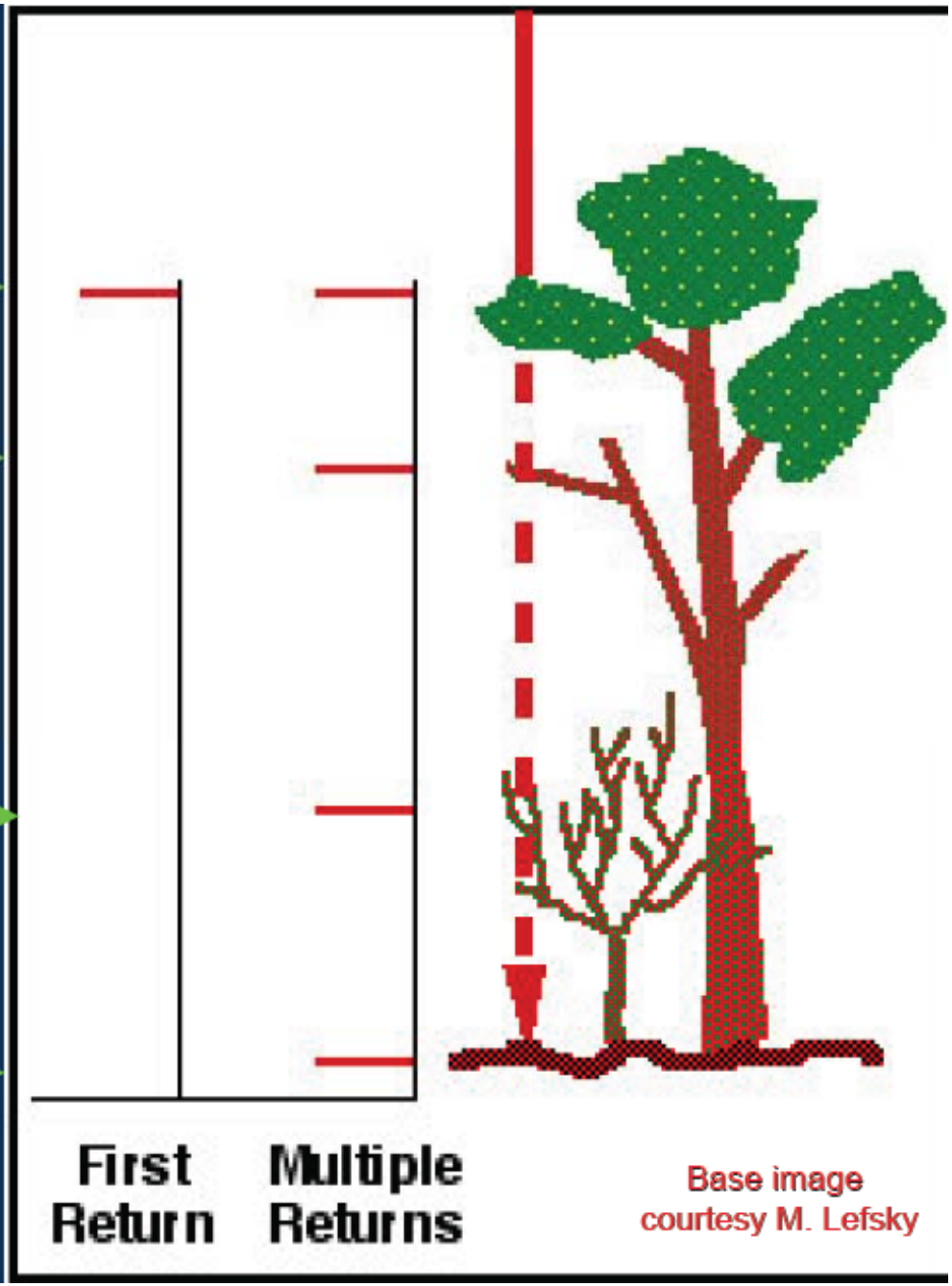
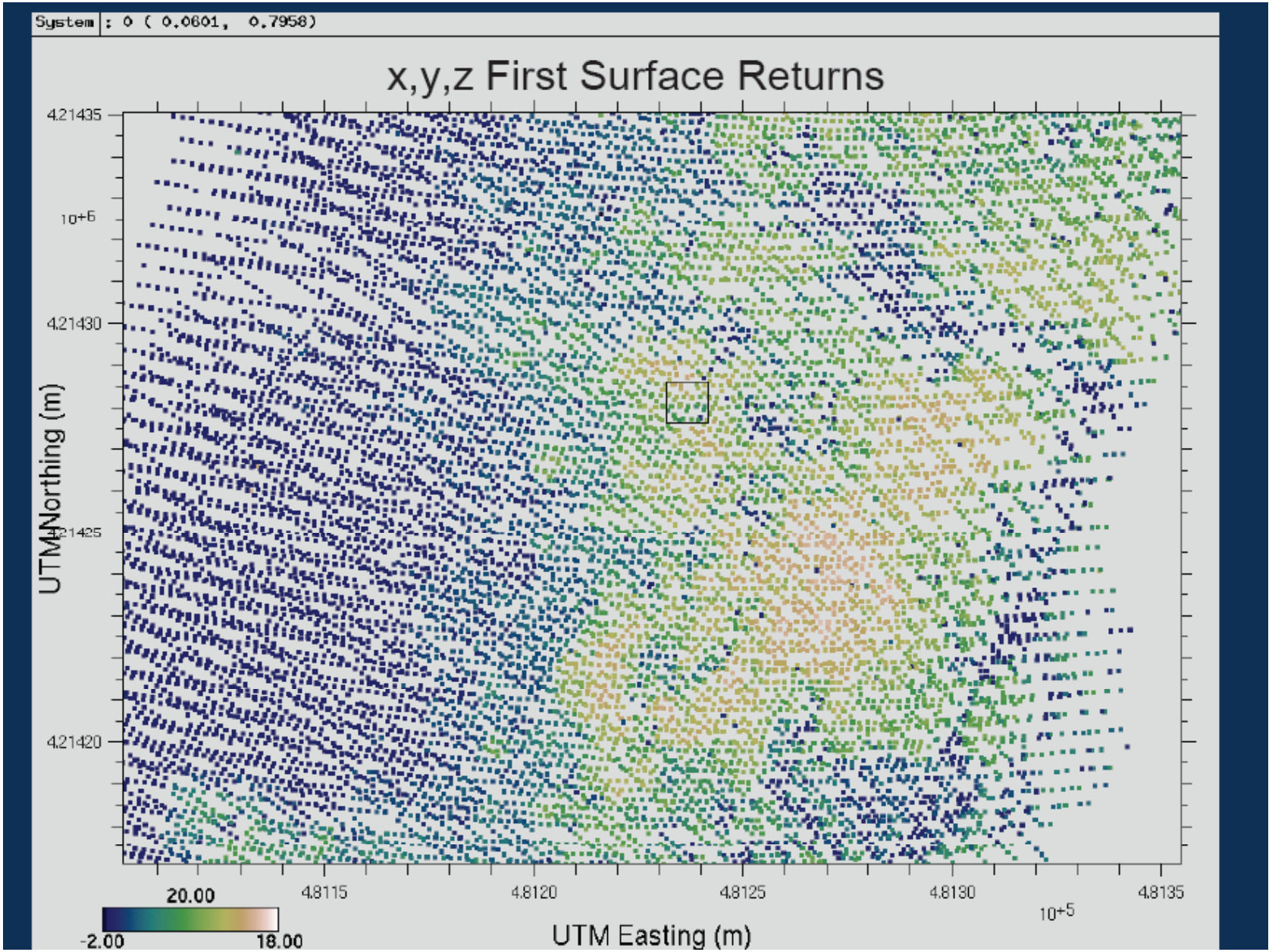
"Multi-Stop" lidars

measure the distances to *multiple* targets ($n \leq 5$) encountered by the laser pulse




System : 0 (0.0601, 0.7958)
x,y,z First Surface Returns
4.21435
10+6
4.21430
4.21425
4.21420
UTM Northing (m)
4.8115
4.8120
4.8125
4.8130
4.8135
10+5
UTM Easting (m)
20.00
-2.00
18.00

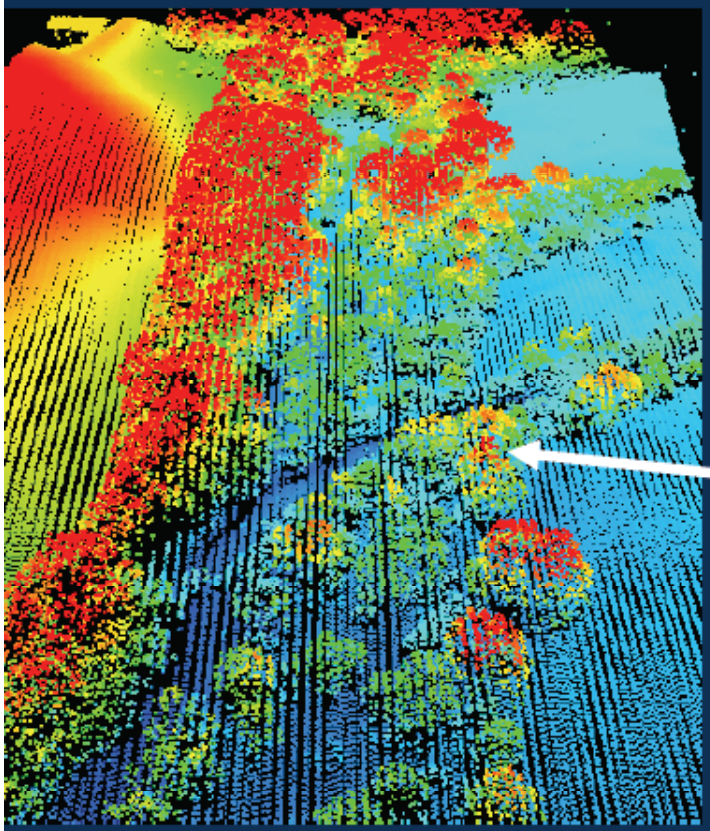
Output data types

- Canopy-top (first return) elevations
- Bare-Earth elevations
- Building models
- Vegetation metrics (multiple return or waveform-resolving systems)
- Intensity returns

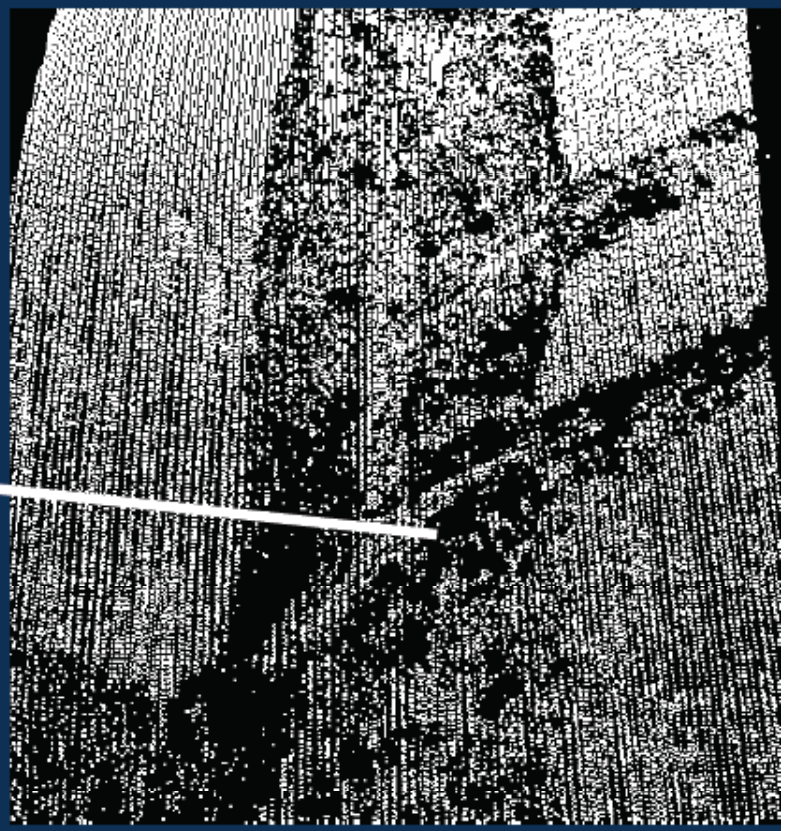
USGS

Vegetation Effects on Terrain Model

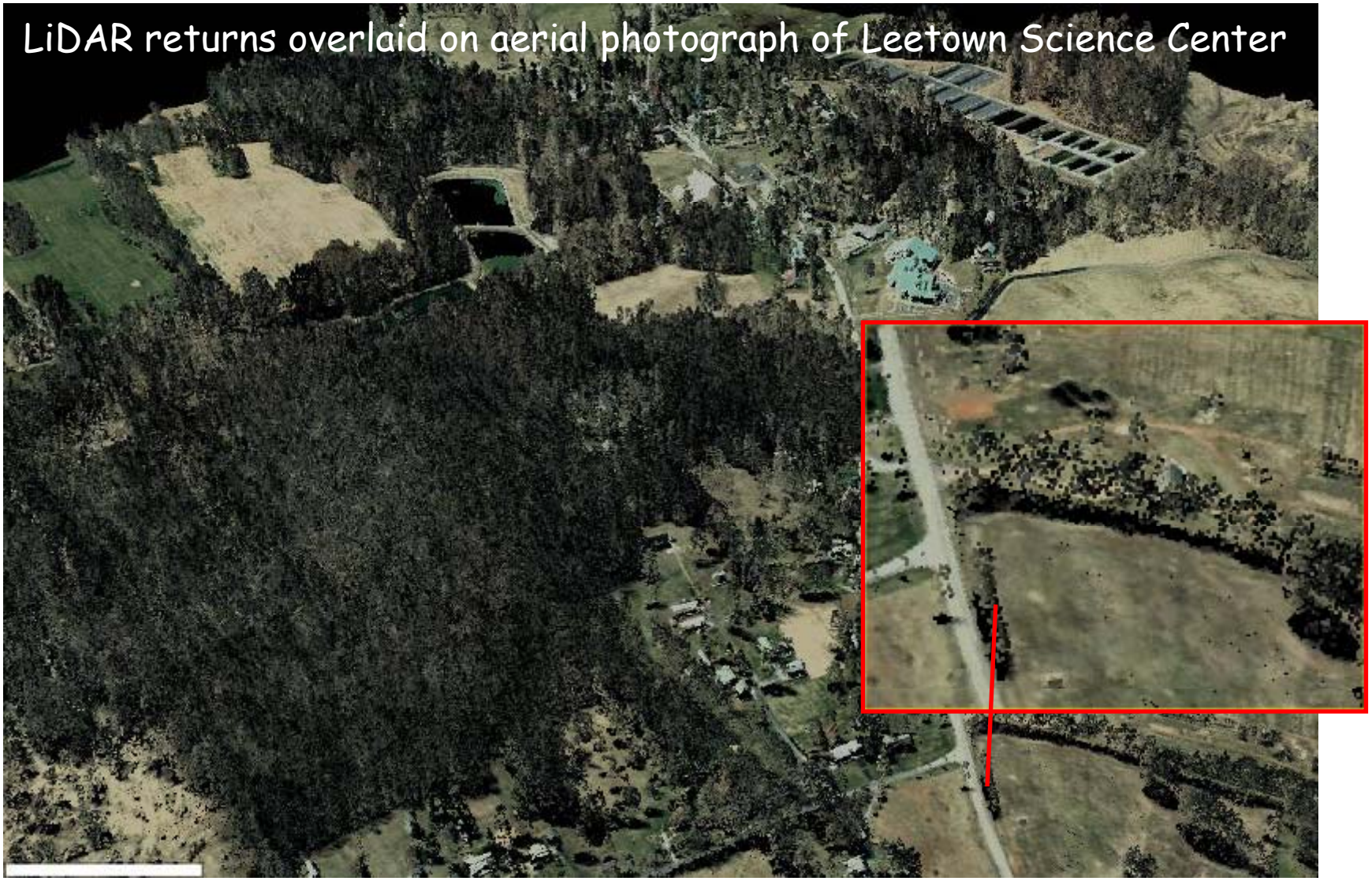
Point Cloud Elevation Stretch



Bare Earth Points used to create surface



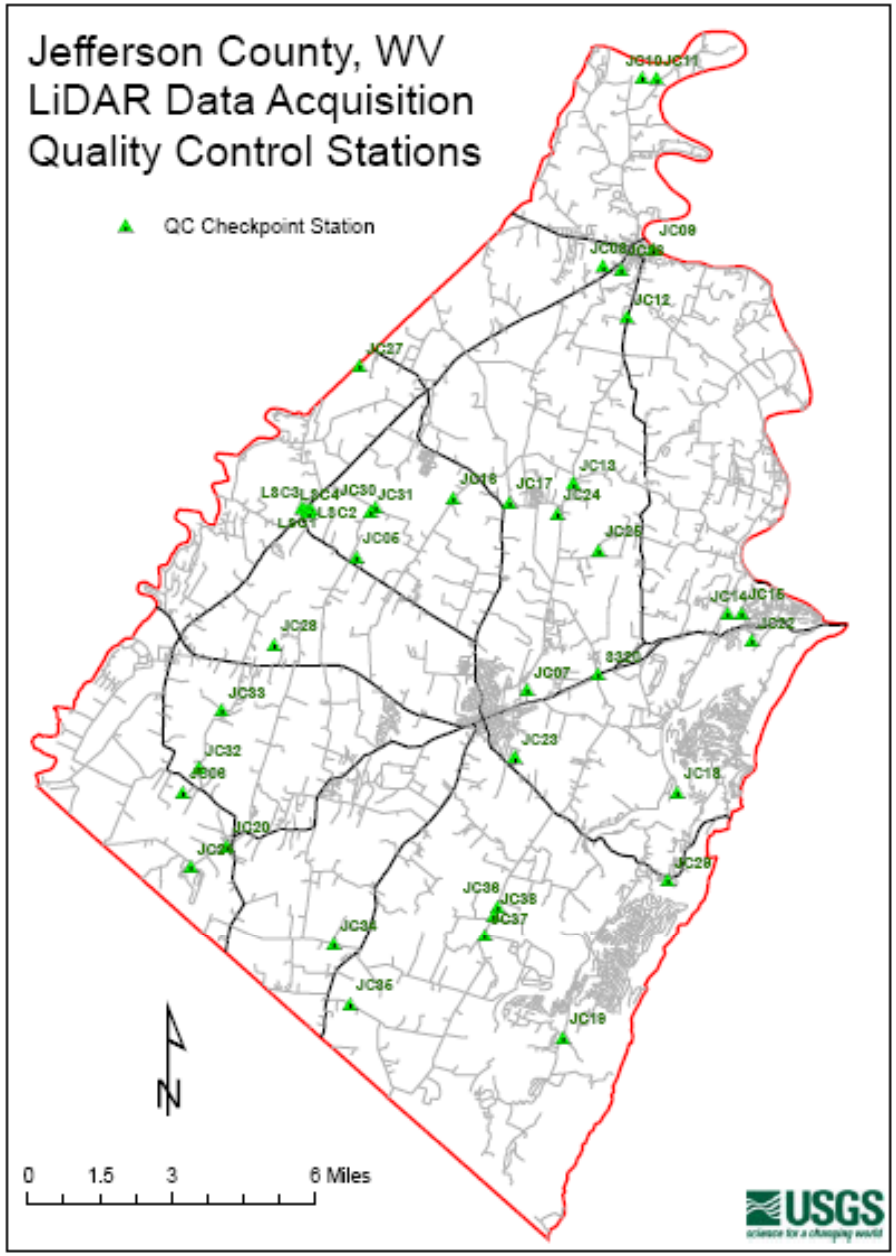
Images courtesy Hans Erik Anderson



LiDAR returns: First (top of canopy, roofs), Last (ground surface)

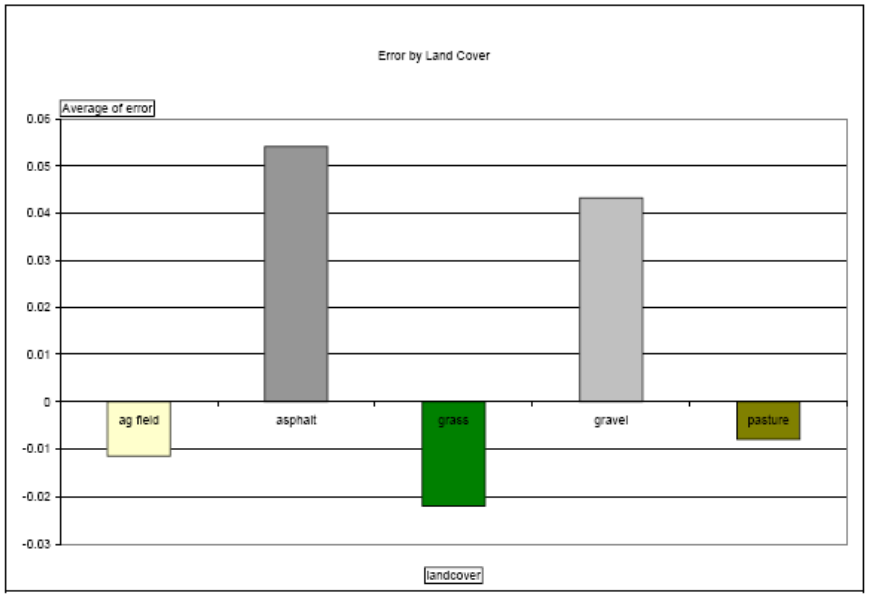
Data Acquisition

- Acquired LiDAR data by partnering with USDA-NRCS
  - Conducted accuracy assessment of LiDAR data acquisition in exchange for access to data
- LiDAR data delivered as first return, last return, and "bare earth" (vegetation and buildings removed)
  - Bare earth processed data still had substantial artifacts from vegetation
  - Needed method to remove remaining vegetation signal to examine landform under forest canopy



USGS QA/QC Campaign:

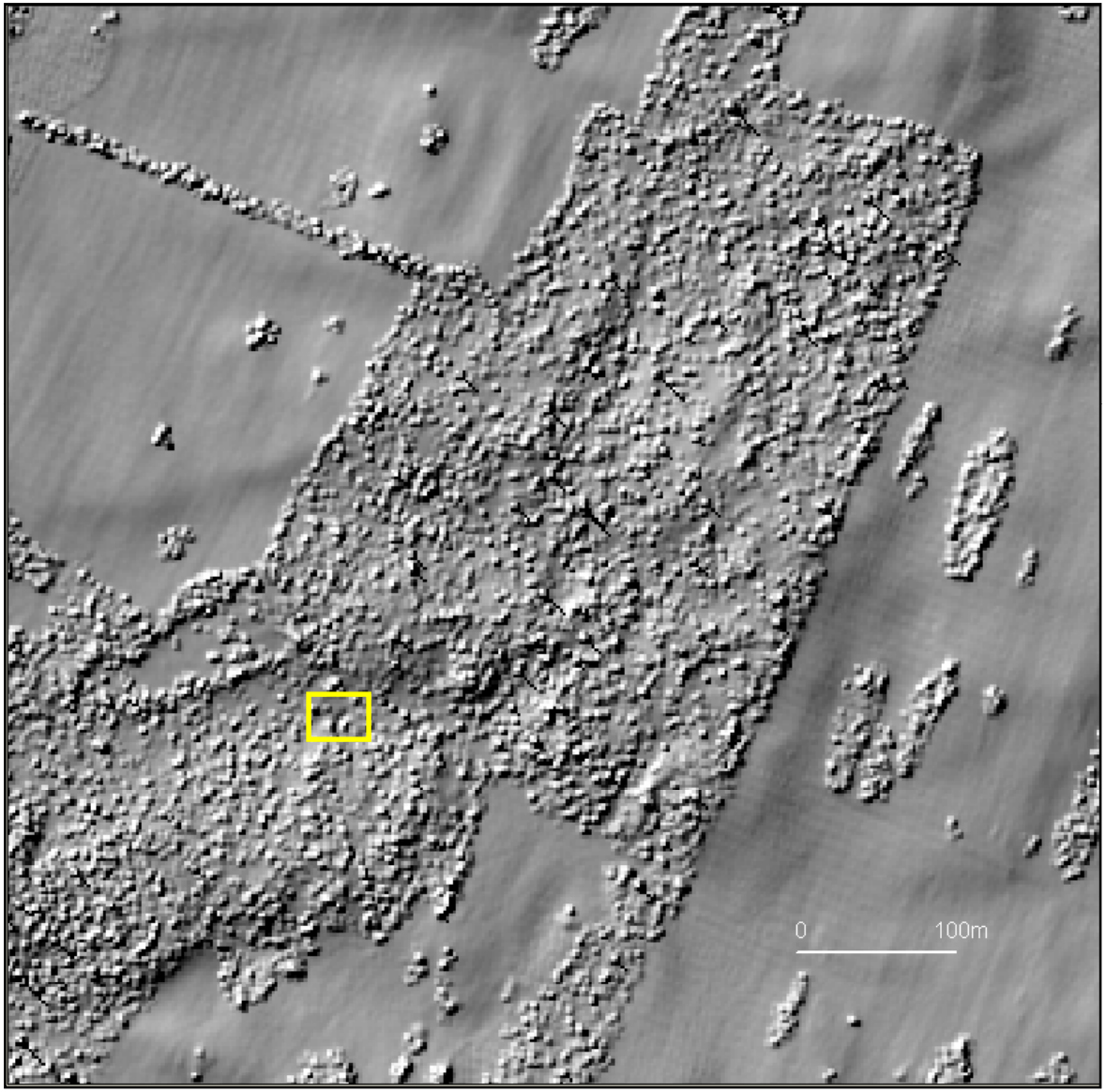
1. 38 stations established throughout county in variety of land surface types
2. Survey-grade GPS used to collect surface height data
3. GPS surface heights compared to mean LiDAR return height within 2 meters of GPS points
4. All but 1 checkpoint were within ± 0.15 meter or less z-value (project spec)



Problem: Find method to locate surface sinks, even under forest canopy

Color Aerial Photo, 0.6 meter pixel resolution, 2003

Data: LiDAR, acquired Spring 2005, delivered Fall 2005

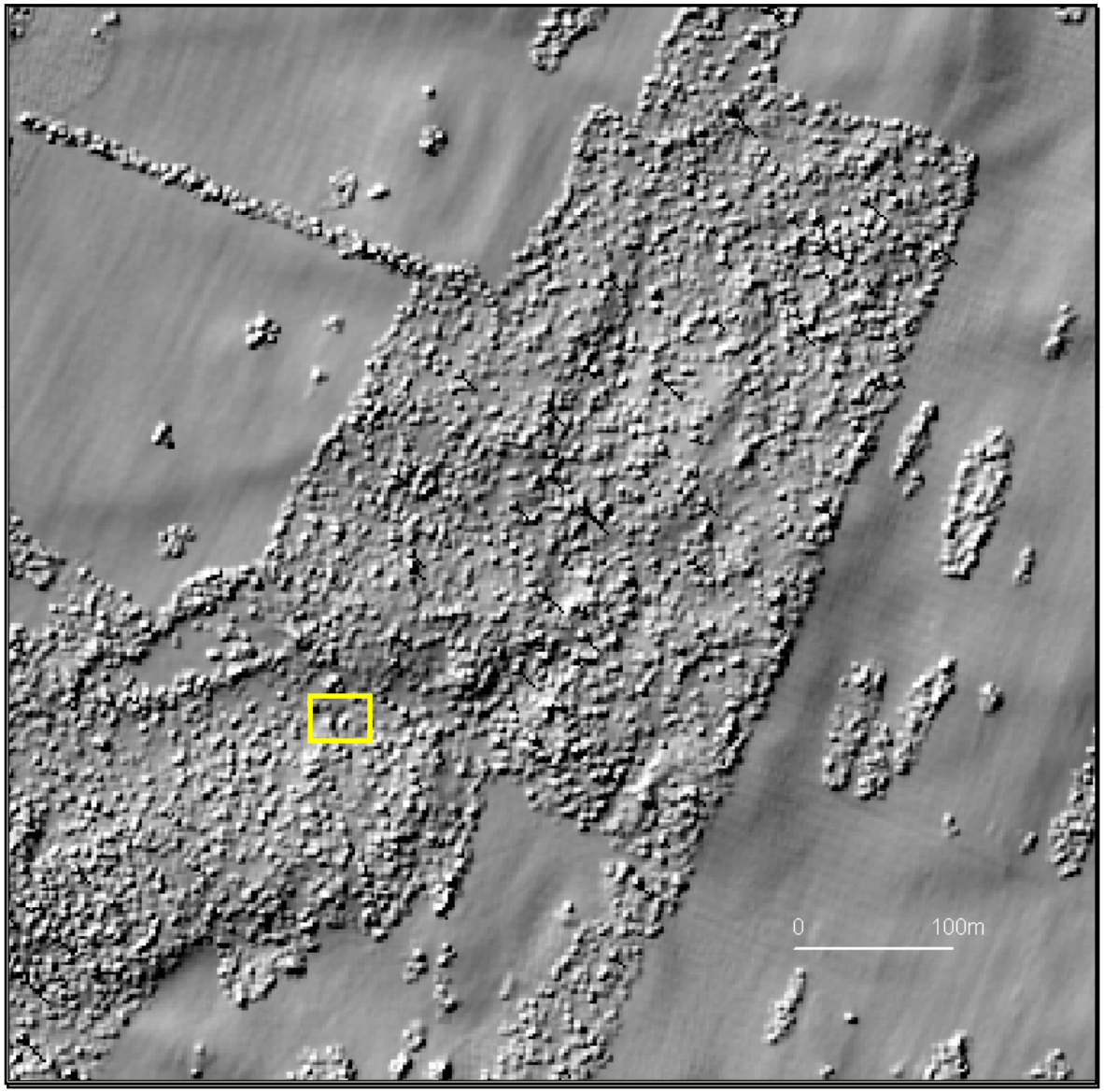


Raw (last return) data gridded to 2m surface

Progressive Curvature Filtering

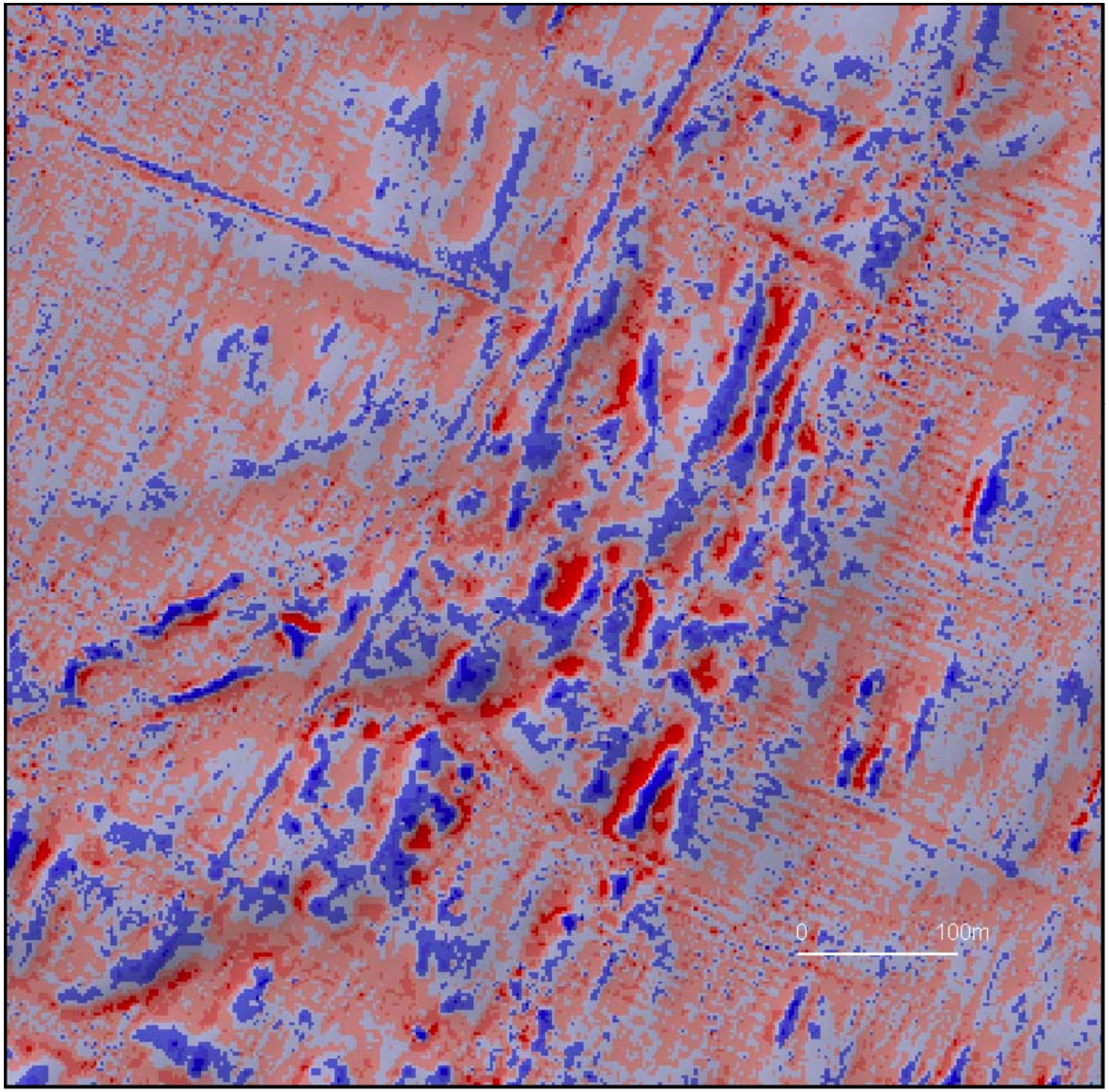
- Evans and Hudak (2007) proposed a method for processing LiDAR data to find ground surface in forests of the interior western U.S.
- Method uses an adaptive, iterative filter that considers scale of variation
  - Fits "thin-plate splines with tension" at multiple scales to examine local curvature and determine which points to filter out
- Effective at removing vegetation

Data processing: Progressive Curvature Filter (Evans and Hudak, 2007)



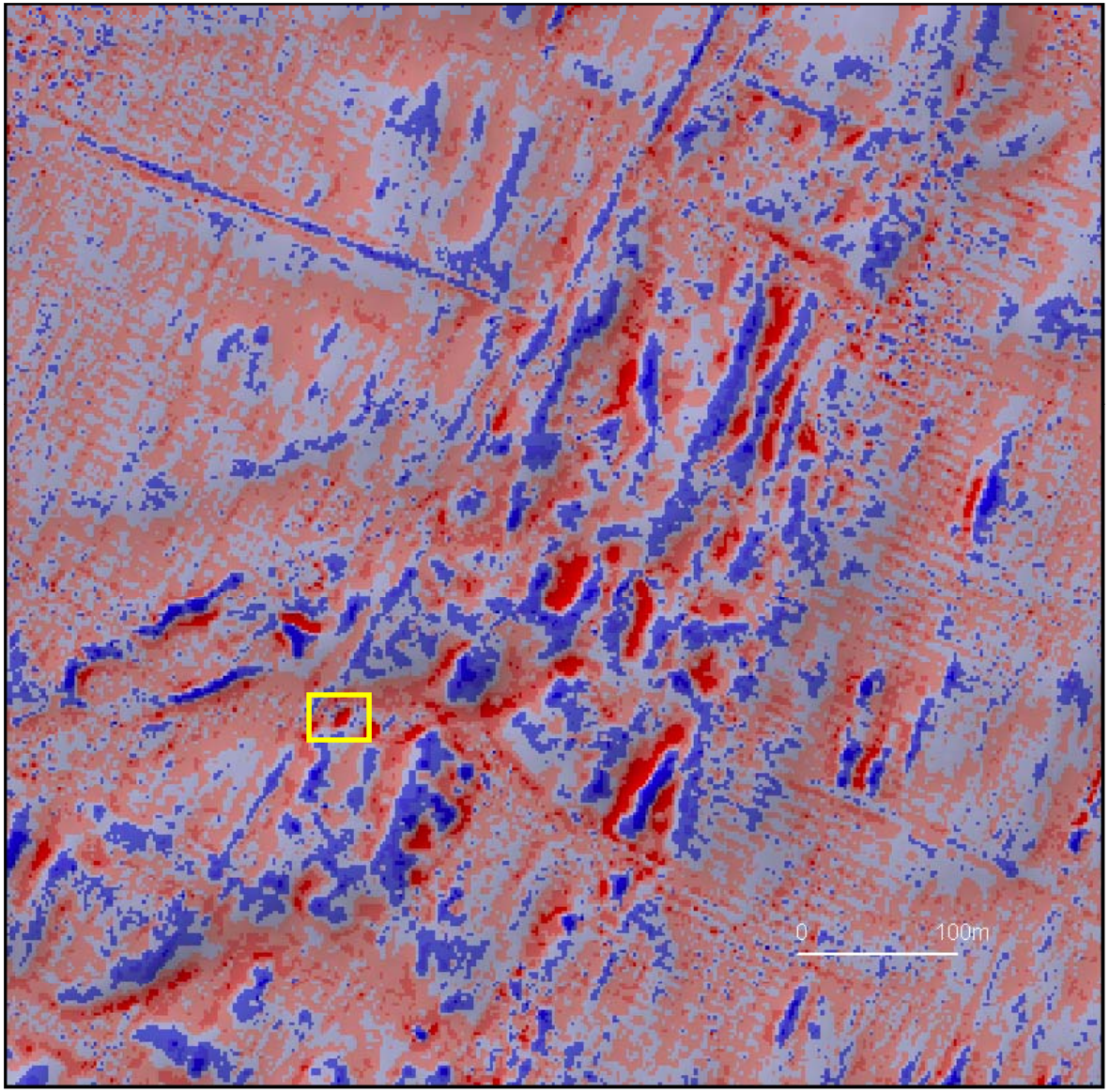
PCF filtered data gridded to 2m surface

Data processing: Landform analysis



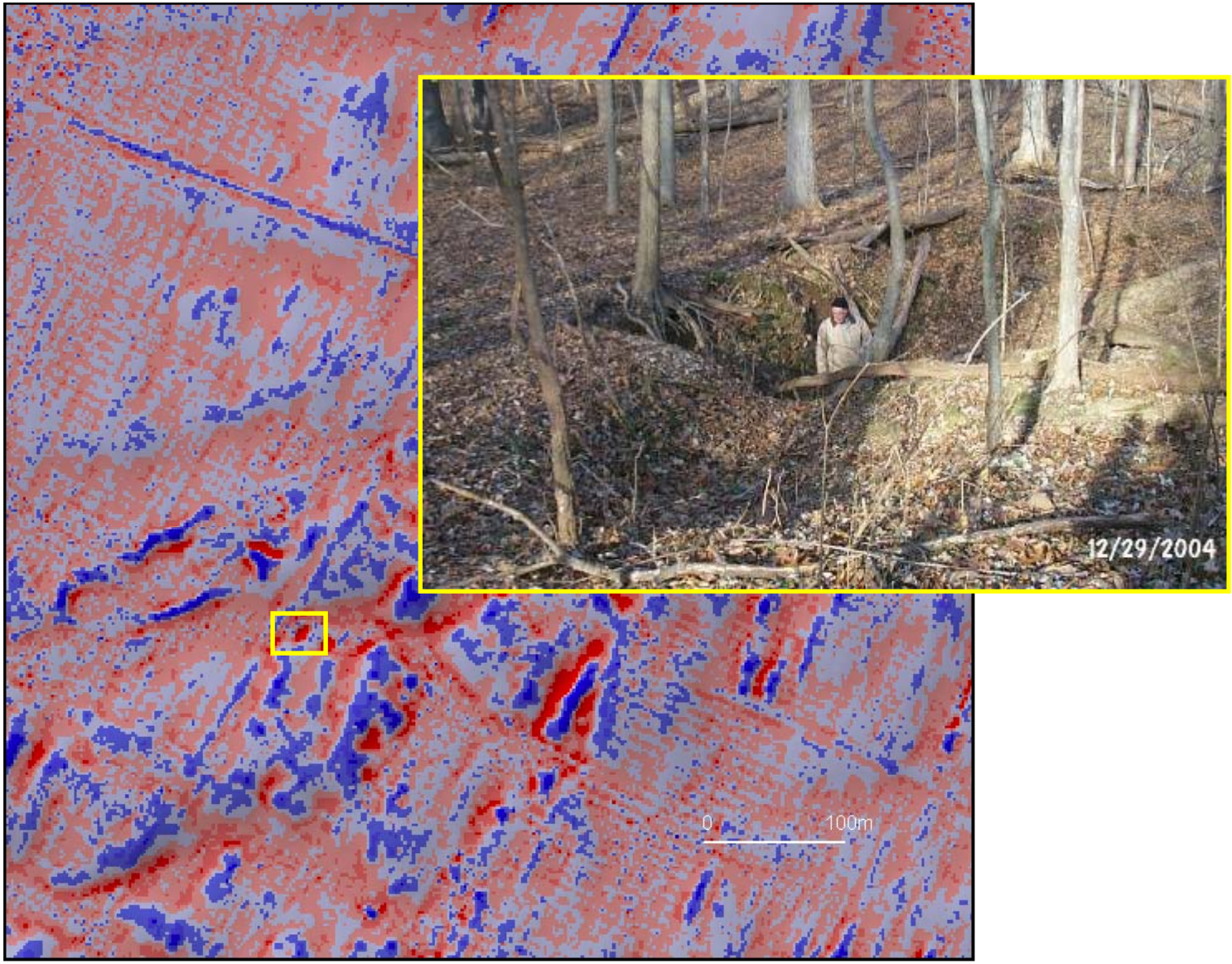
Landform shape in 10 m window, red = concave, blue = convex

Data processing: Landform assessment



Find compact bowl features, possible sinkholes

Field Verification



Sinkhole confirmed !

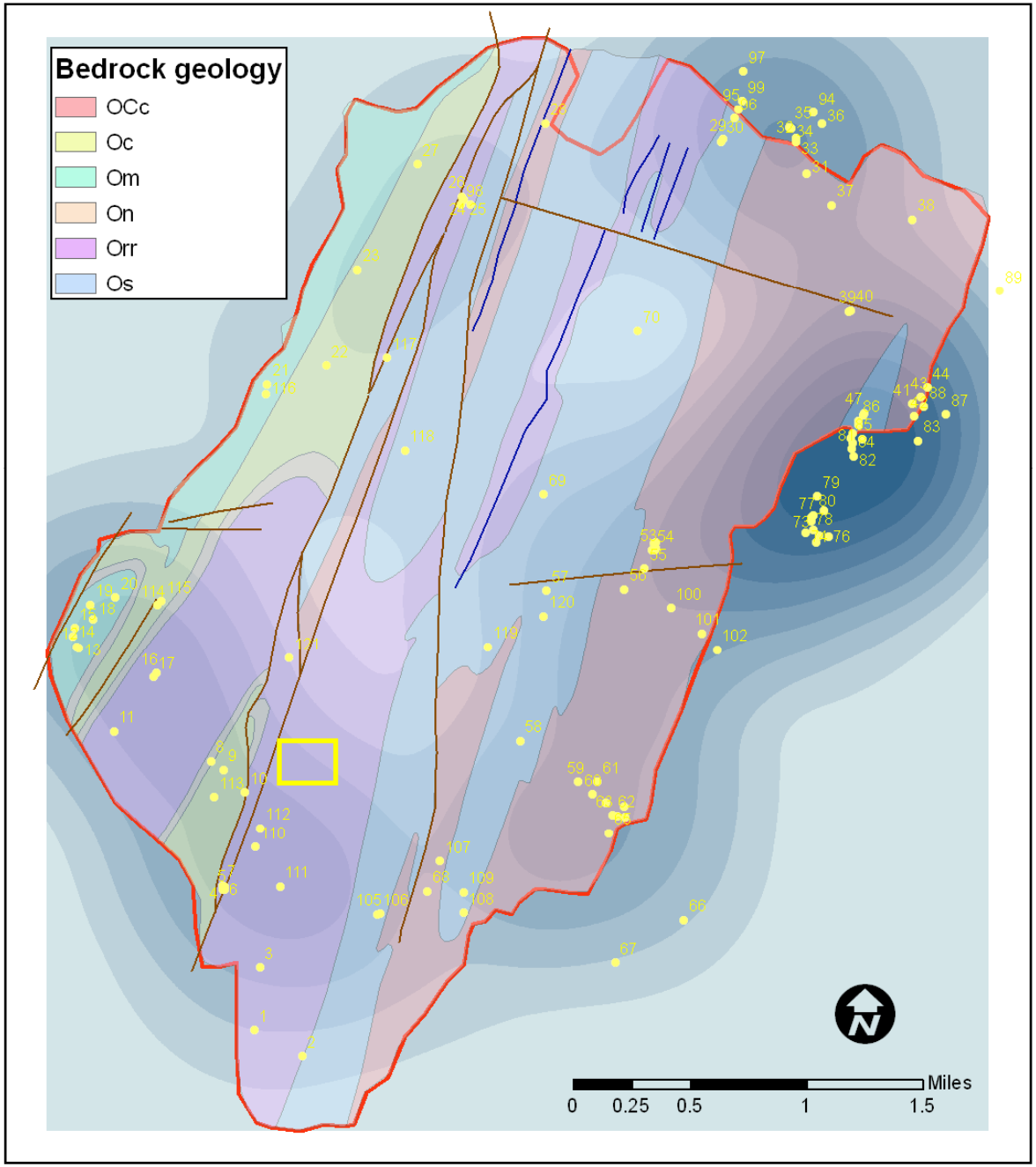
Another view of the sinkhole…

Field validation results

94 sites mapped, 55 visited on ground

Other LiDAR applications

- Surface geology (bedding, etc.)
- Sinkhole susceptibility by geologic formation
- Structure / Fault line tracing
- Hydrologic flow anomalies
- Vegetation height/structure
- Landslides / slumping
- Landscape visualization / 3D modeling


Bedrock geology
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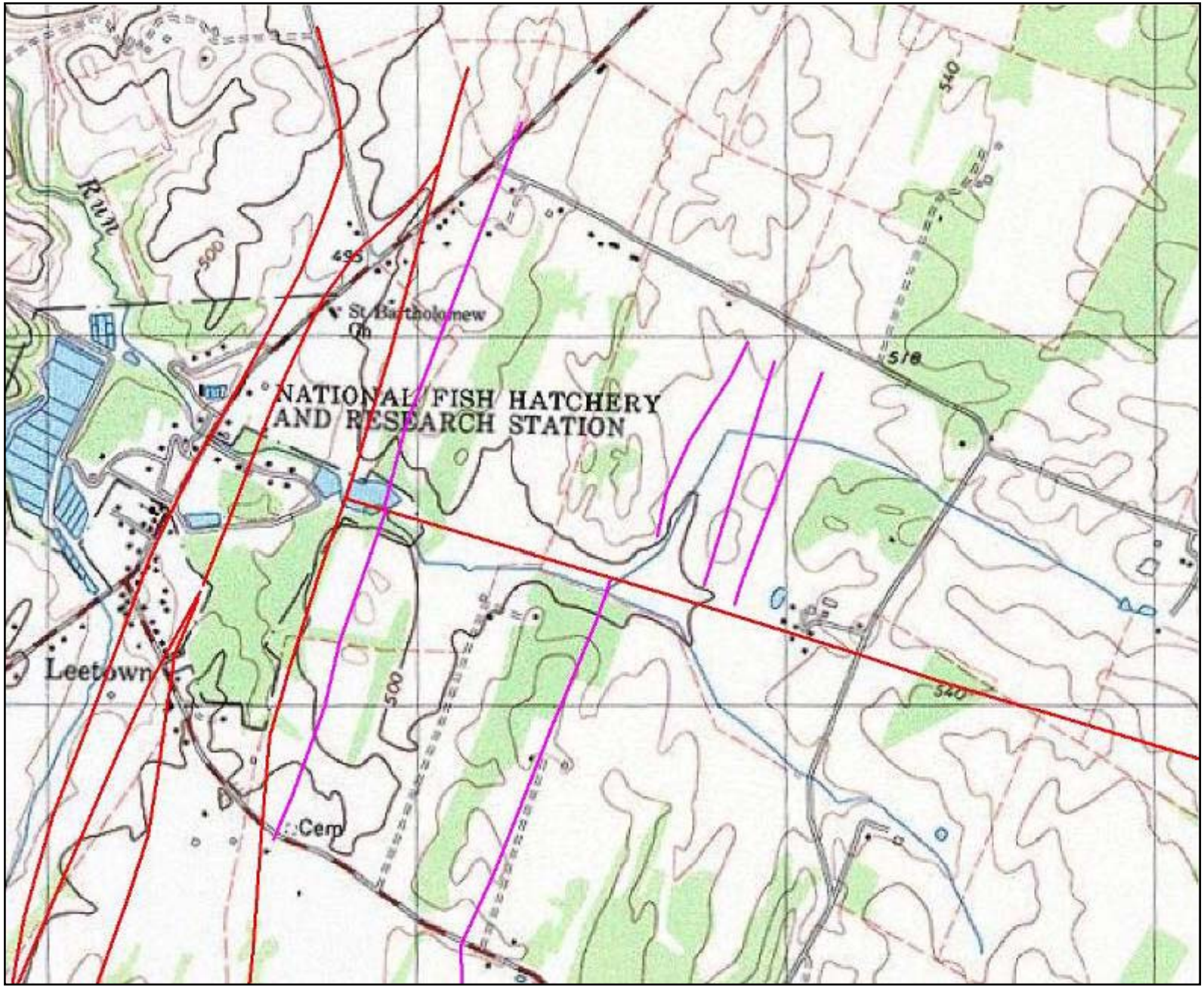
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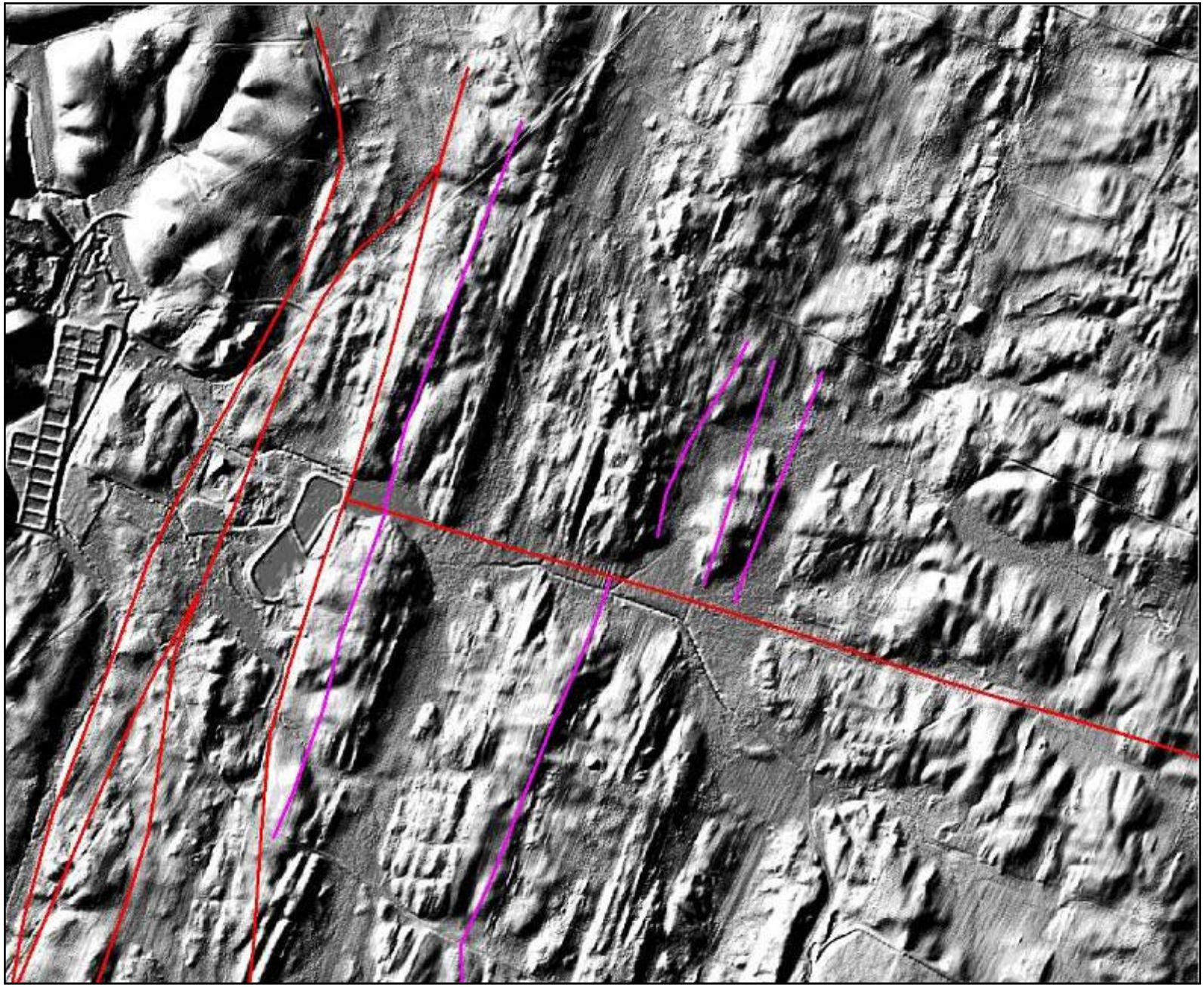
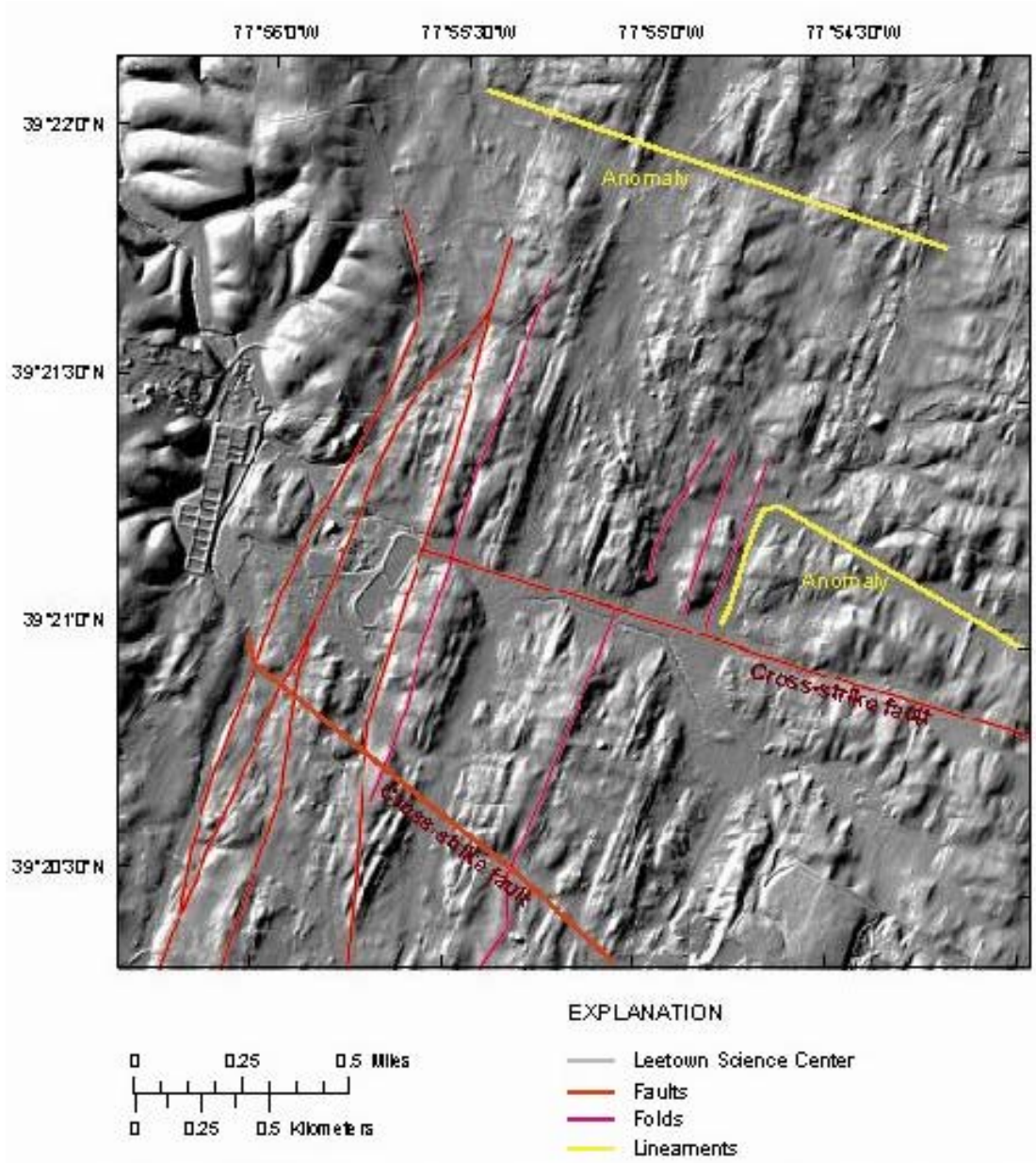
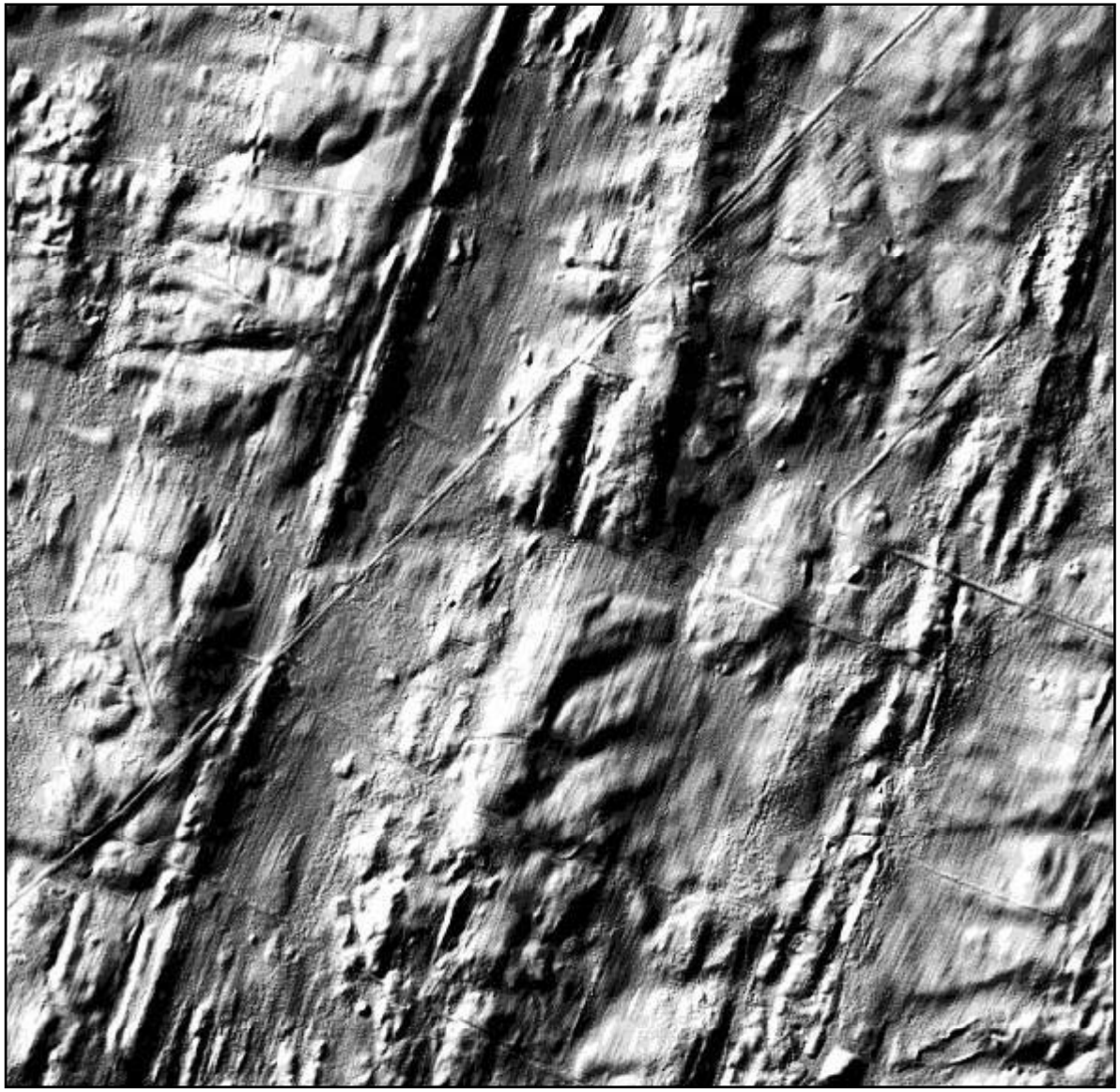


Leetown LiDAR DEM

- The LiDAR DEM was used as the upper layer of the hydrologic flow model.

- LiDAR imagery aided in identifying anomalous areas within the model and helped resolve issues with elevated heads in certain areas.





For additional info, contact John Young (jyoung@usgs.gov)

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