Applying Precision Conservation Tools

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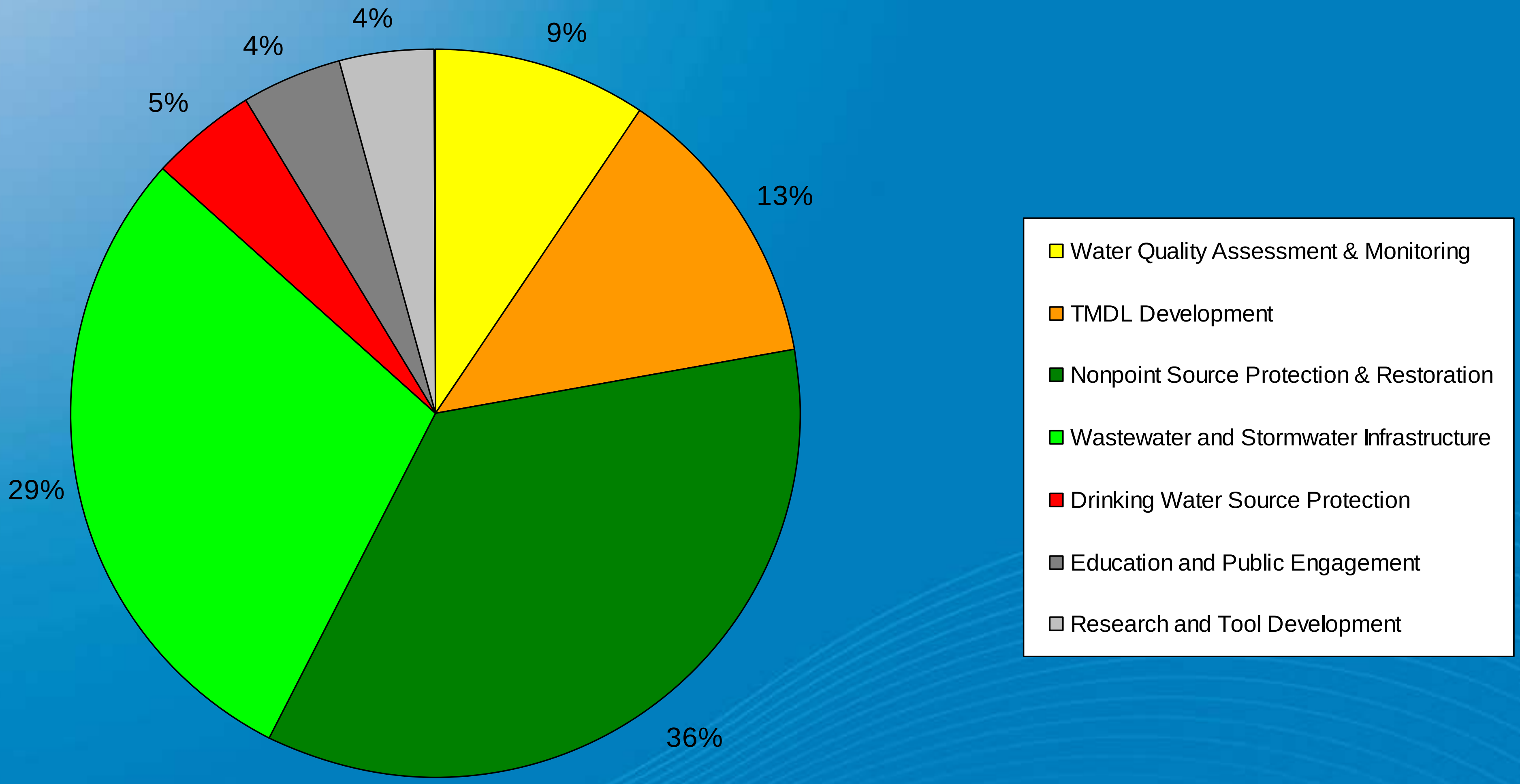
Constitutional Amendment
(Article XI.Section 15)

- Beginning July 1, 2009, until June 30, 2034, the sales and use tax rate shall be increased by three-eighths of one percent on sales and uses taxable under the general state sales and use tax law
- 33 percent of the receipts shall be deposited in the Clean Water Fund
- $152M in FY10-FY11
- Passage of the constitutional amendment provides funding for protection, restoration and enhancement of impaired waters

Summary of Clean Water Fund FY2010-FY2011 Budget by Function



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Clean Water Funding Initiatives

- Funding from the Clean Water Fund should be spent on the most critical landscapes and sources of degradation rather than spread evenly across the state
- There is a pressing need to identify critical sources of water quality degradation and their locations in order to select and implement BMPs

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Precision Conservation

- "…set of spatial technologies and procedures to implement conservation management practices that integrates spatial and temporal variability across natural and agricultural systems."
  - Berry et al. 2003
- "Getting the right practices, in the right places, at the right time, and at the right scale is what makes conservation effective."
  - Cox 2005

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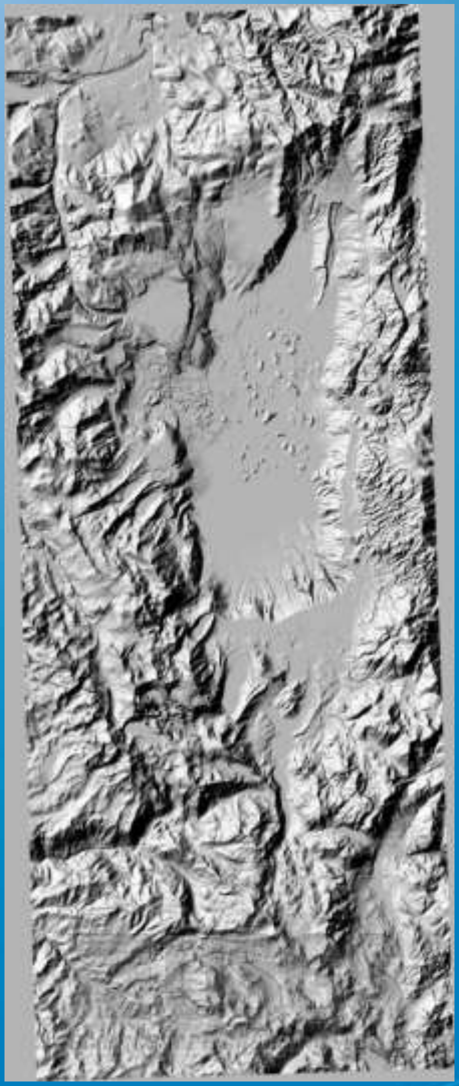
Critical Areas

- Small areas in the landscape (5-25%) that deliver disproportionate loads of nonpoint source pollution to the watershed outlet
- Reduction of nonpoint source pollution loads is dependent on the implementation of best management practices (BMPs) in these critical source areas
- Defining critical source areas is a challenge, but new elevation technology may provide water resource managers with effective implementation tools

Digital Elevation Model



What is a DEM?

- Digital file that:
  - Contains elevation of terrain over a specified area
  - Is arranged as a fixed-grid interval over the earth surface
  - Is geo-referenced
  - Can be manipulated to create other elevation-dependent data products

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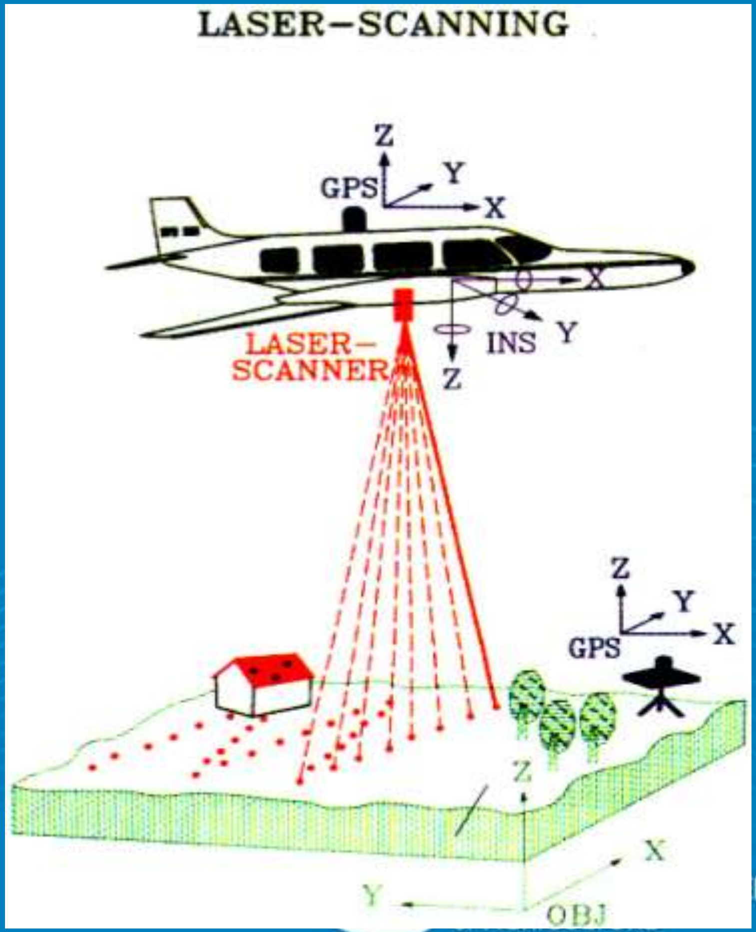
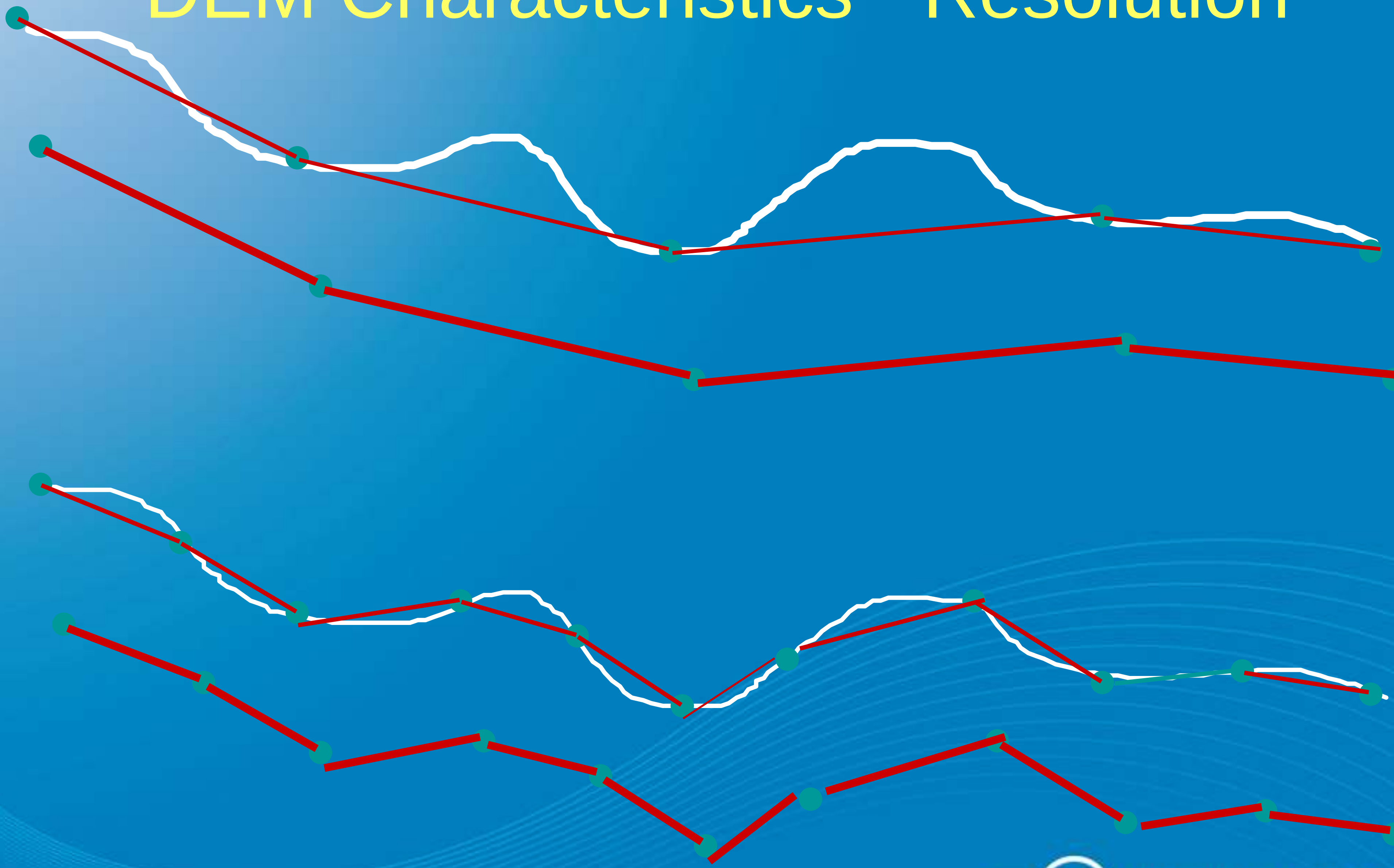
DEM Sources: LiDAR

- Light Detection And Ranging (LIDAR)
- Uses lasers to emit light pulses that strike ground & reflect back to airborne sensor
- Precise altitude & position of aircraft known
- Elevation of surface points determined based on time for pulse to return to sensor
- Much higher spatial resolution than existing elevation data



DEM Characteristics - Resolution



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DEM Comparison

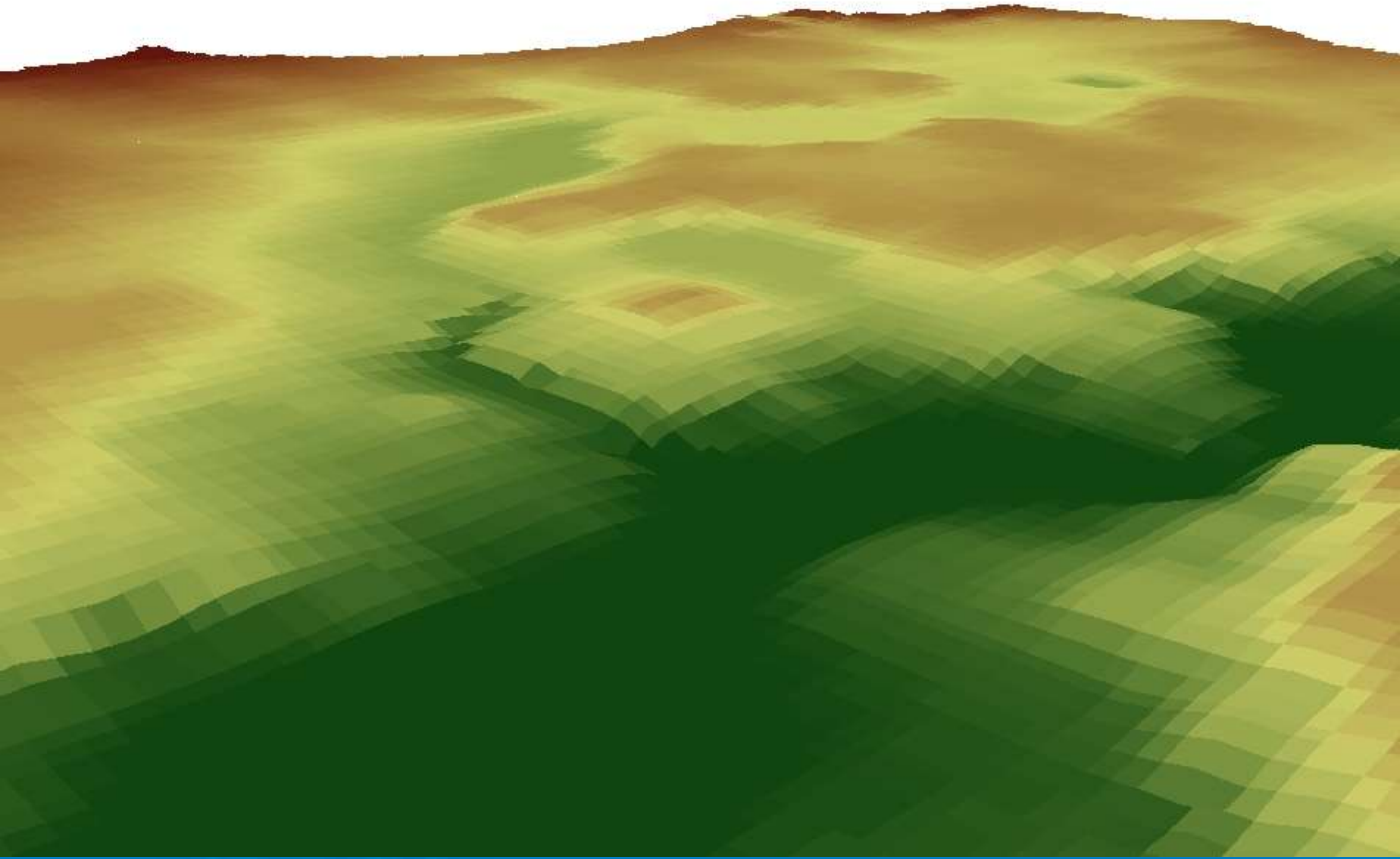
Why so much interest in LIDAR?

- Higher resolution data than we ever thought possible
- Opens up opportunities to describe and characterize landscapes in ways previously not feasible

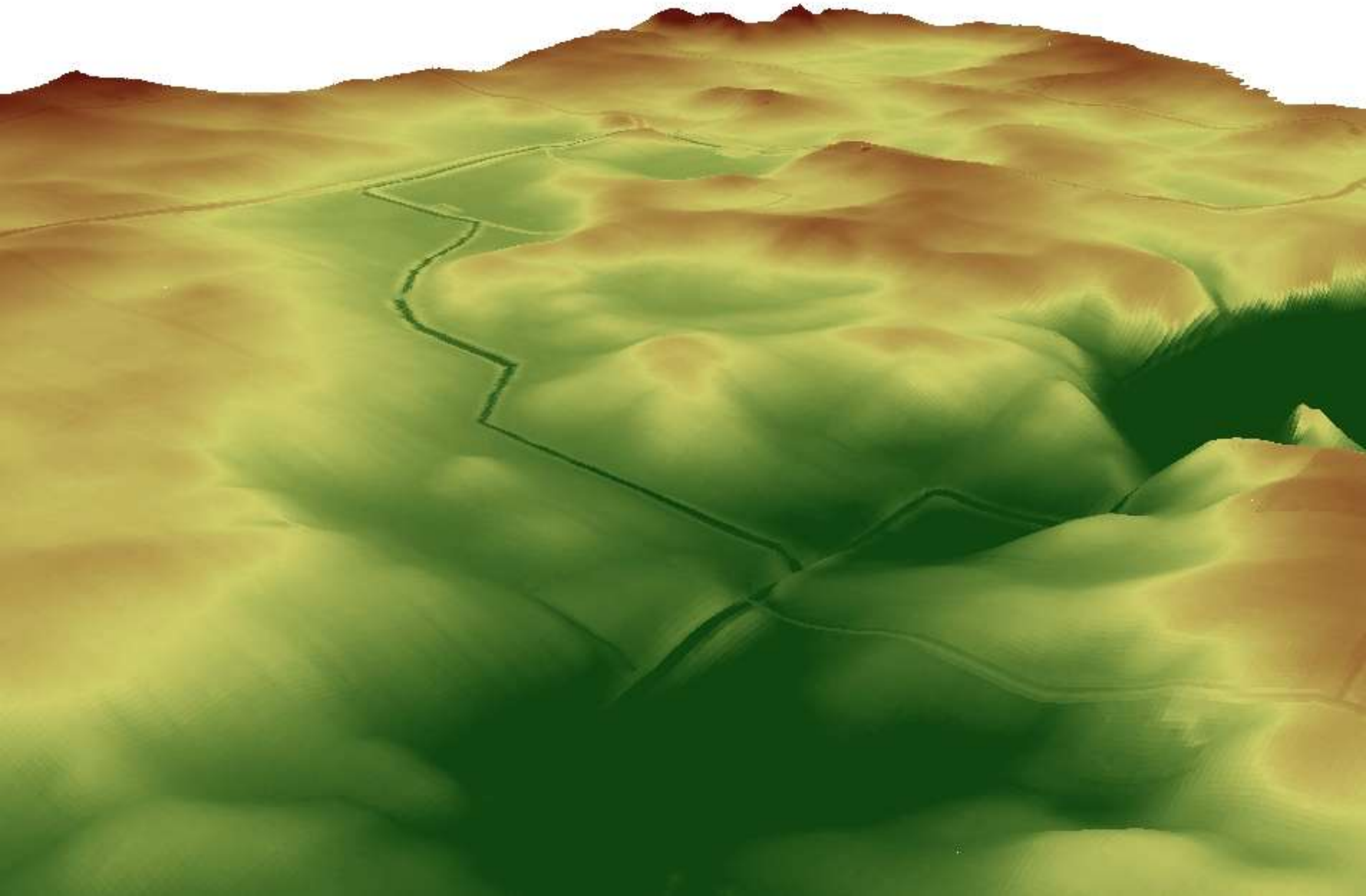
Comparison to existing national standard product

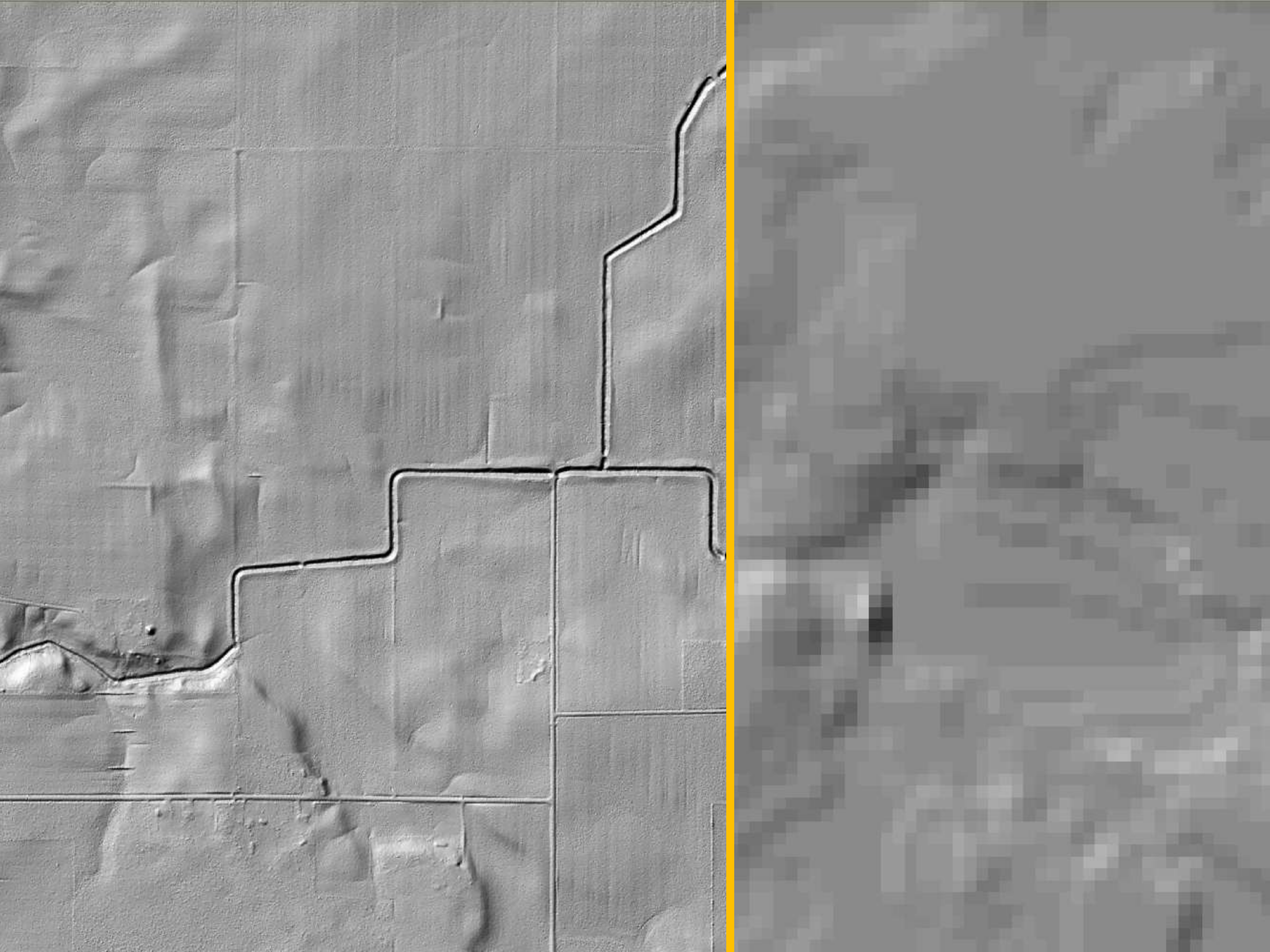
	USGS DEM	LiDAR DEM
Horizontal Resolution	**30 meters**	**1 meter**
Vertical Resolution	**7-15 meters**	**15 cm**
Contour Interval	**5-20 feet**	**1-3 feet**

USGS 30 meter Elevation Data

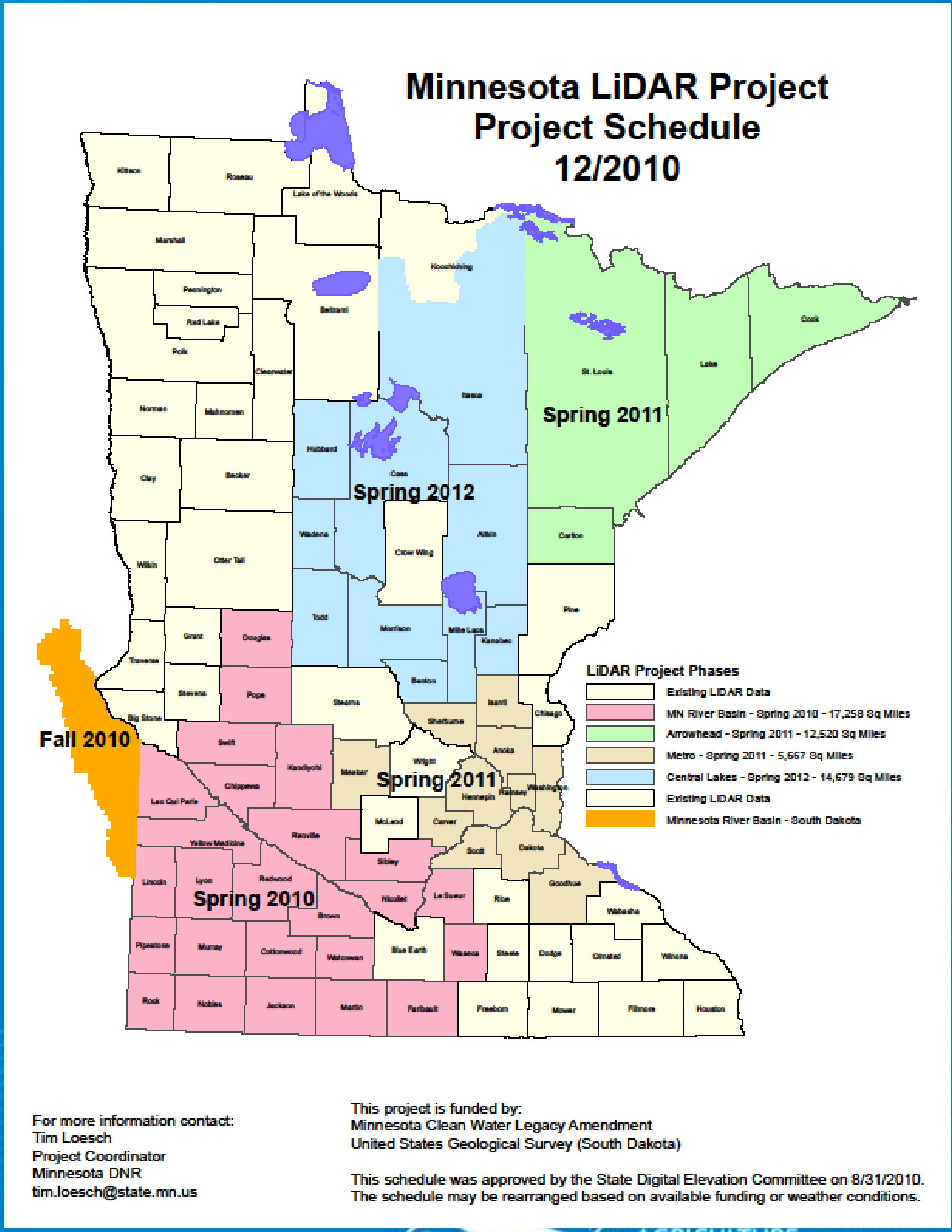


LiDAR 3 meter Elevation Data





- 25 Minnesota counties currently have LiDAR data available
- Statewide LiDAR acquisition has been funded by the Clean Water Fund ($5.6 million)
- To be completed in 2012



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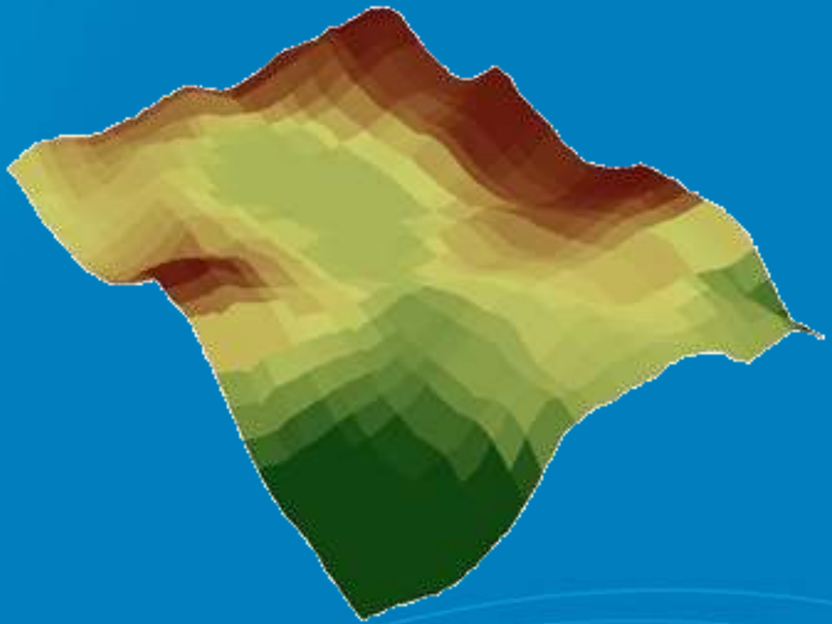
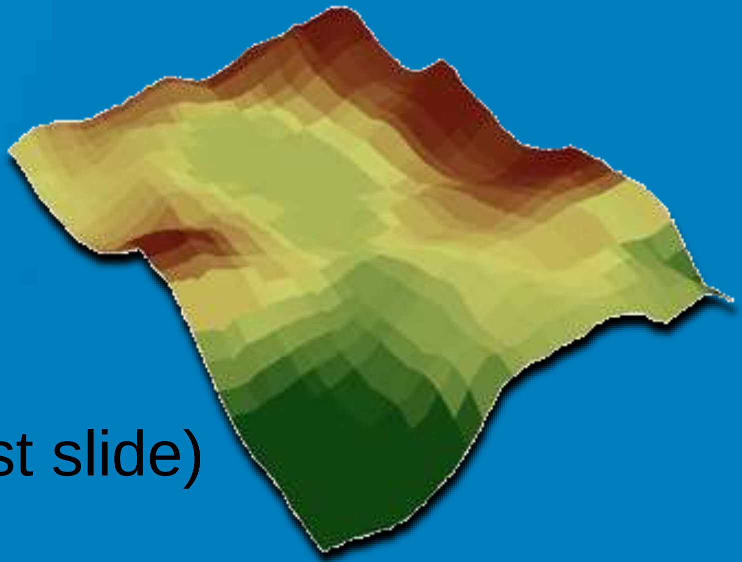
LiDAR Applications: Terrain Analysis

What is it? Many things:

- Includes use of a DEM to model the landscape
- Provides a quantitative, detailed, objective, repeatable process to accurately model real landscape processes
- Helps describe, analyze, and interpret any feature related to topography – soils, vegetation, wildlife, etc.



Terrain Analysis History



- Concept is over 20 years old
- Early pioneers Wilson, Gallant, Moore, Gessler
  - Terrain Analysis: Principles and Applications (see references, last slide)
- Early applications:
  - Soil Mapping
  - Hydrologic Mapping
  - Wildlife/Habitat Modeling
- LiDAR is creating renewed interest in terrain analysis
- Significant implications for conservation

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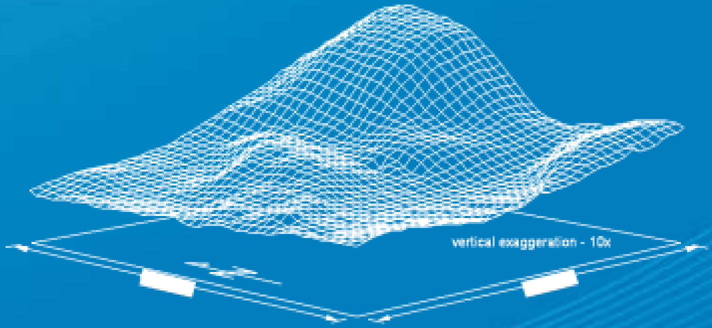
Advantages of Terrain Analysis

- Coupled with GIS/remote sensing, enables fast, accurate characterization of large areas (days vs. months)
- Quantitative, repeatable, and non-subjective
- Helps describe, analyze, and interpret any feature related to topography (soils, vegetation, wildlife, etc.)
- Results in spatial data, not just numerical data
- Fits the level of detail needed for conservation planning



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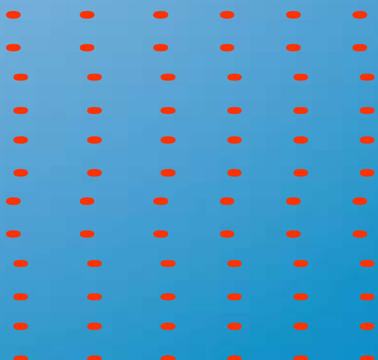
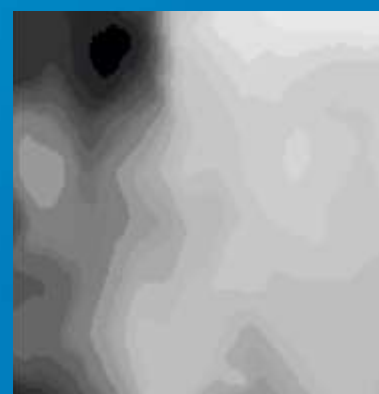
Digital Terrain Analysis Overview Example

Point Elevations with GPS



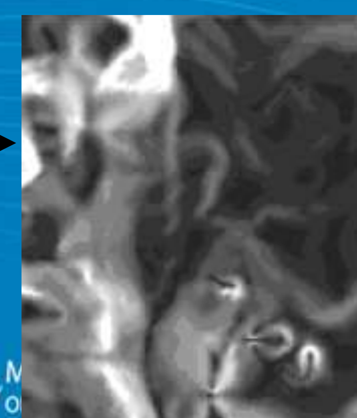
Spatial Interpolation

DEM



Attribute Calculation

Terrain Attributes

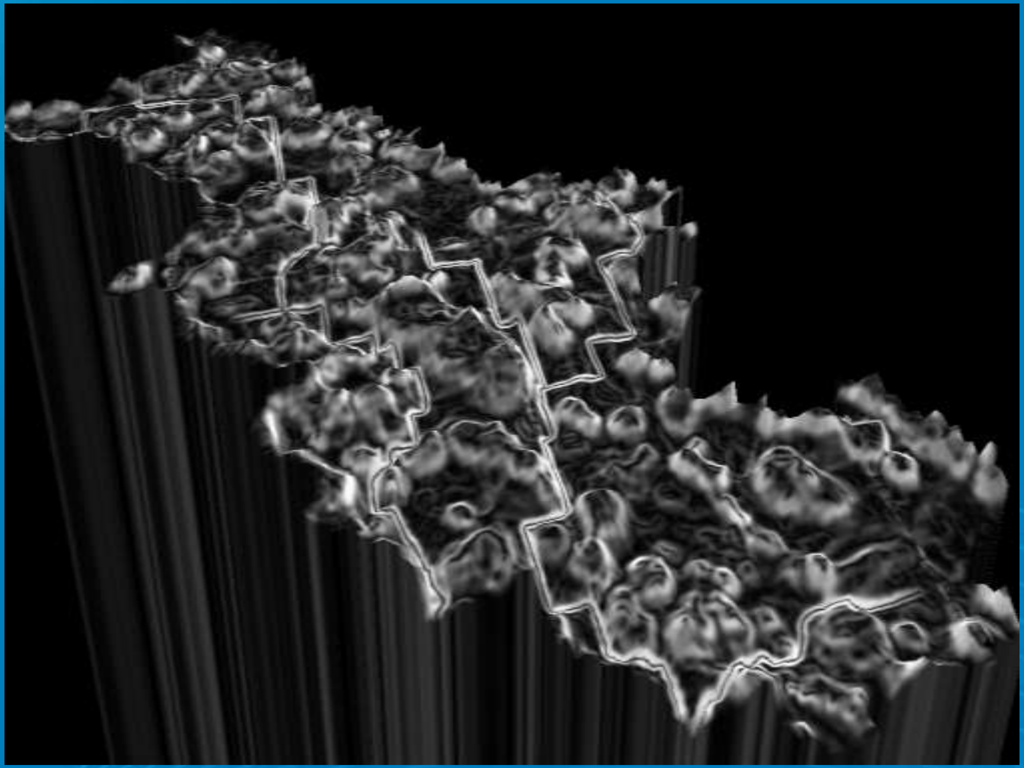


Terrain Attributes

- Primary and secondary
- Primary attributes calculated directly from elevation data
  - Examples: Aspect, Slope, Flow Accumulation, Profile Curvature, Plan Curvature
- Secondary (compound) attributes involve combinations of primary attributes – the are indices
  - Indices describing the spatial variability of specific landscape processes, such as the potential for sheet erosion (Moore et al., 1991)
  - Examples: Stream Power Index, Wetness Index

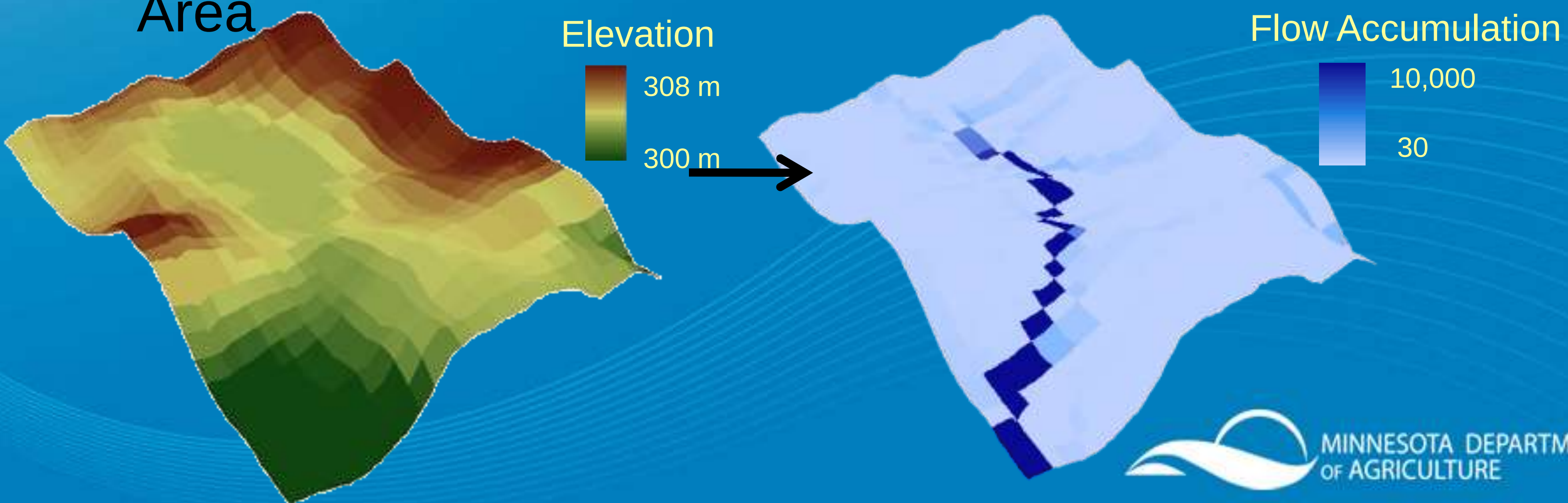
Primary Terrain Attributes
Slope

- Describes overland and subsurface flow velocity and runoff rate
- Quantifies maximum rate of change in value from each cell to its neighbors



Primary Terrain Attributes
Flow Accumulation

- A measure of surface or shallow subsurface runoff at any given point on the landscape
- Combines effects of upslope surface drainage area and convergence of runoff
- Represents drainage area of any given cell
- Indicates overland flow paths
- Also called Catchment Area or Upslope Contributing Area



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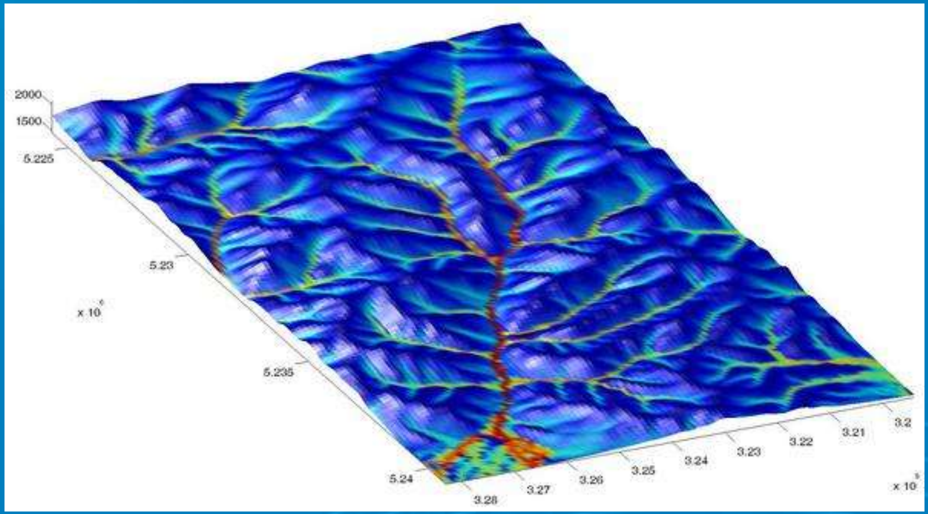
Primary Terrain Attributes
Flow Accumulation

Use/Significance

- Runoff volume
- Steady-state runoff rate
- Soil characteristics
- Soil-water content
- Geomorphology



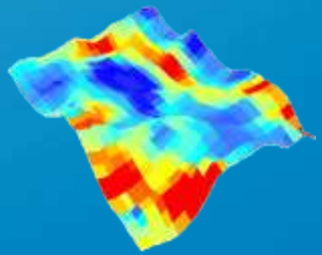
Secondary Terrain Attributes

- Second derivative calculations (combinations of primary terrain attributes)
  - Compound Topographic Index (CTI)
  - Stream Power Index (SPI)

Secondary Terrain Attributes
Stream Power Index (SPI)

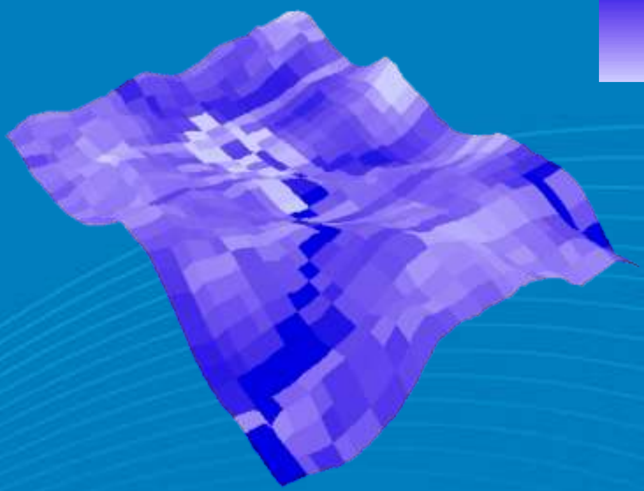
- Product of Slope and Flow Accumulation
- Quantifies the potential erosive power of overland flow
- Isolates areas with large catchments and steep slopes

ln (A * Slope) = **Stream Power Index (SPI)**



X

=



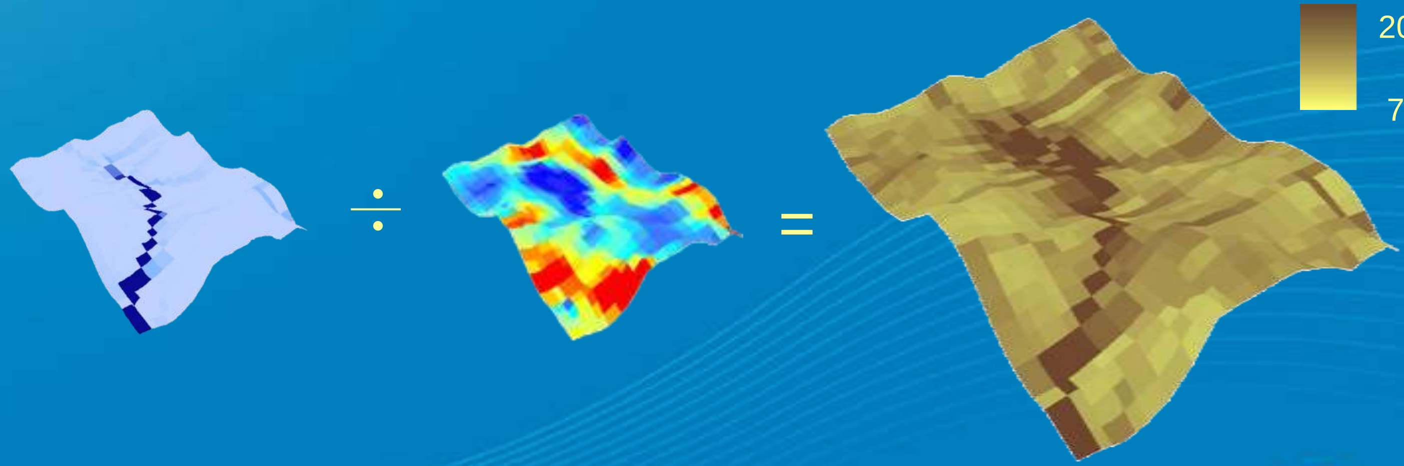

Stream Power Index
0
40
80
160 Meters

Secondary Terrain Attributes

Compound Topographic Index (CTI)

- Flow Accumulation divided by Slope
- Identifies areas where water collects or ponds on the landscape
- Also called Steady State Wetness Index or just Wetness Index

ln (A / Slope) = **Compound Topographic Index (CTI)**



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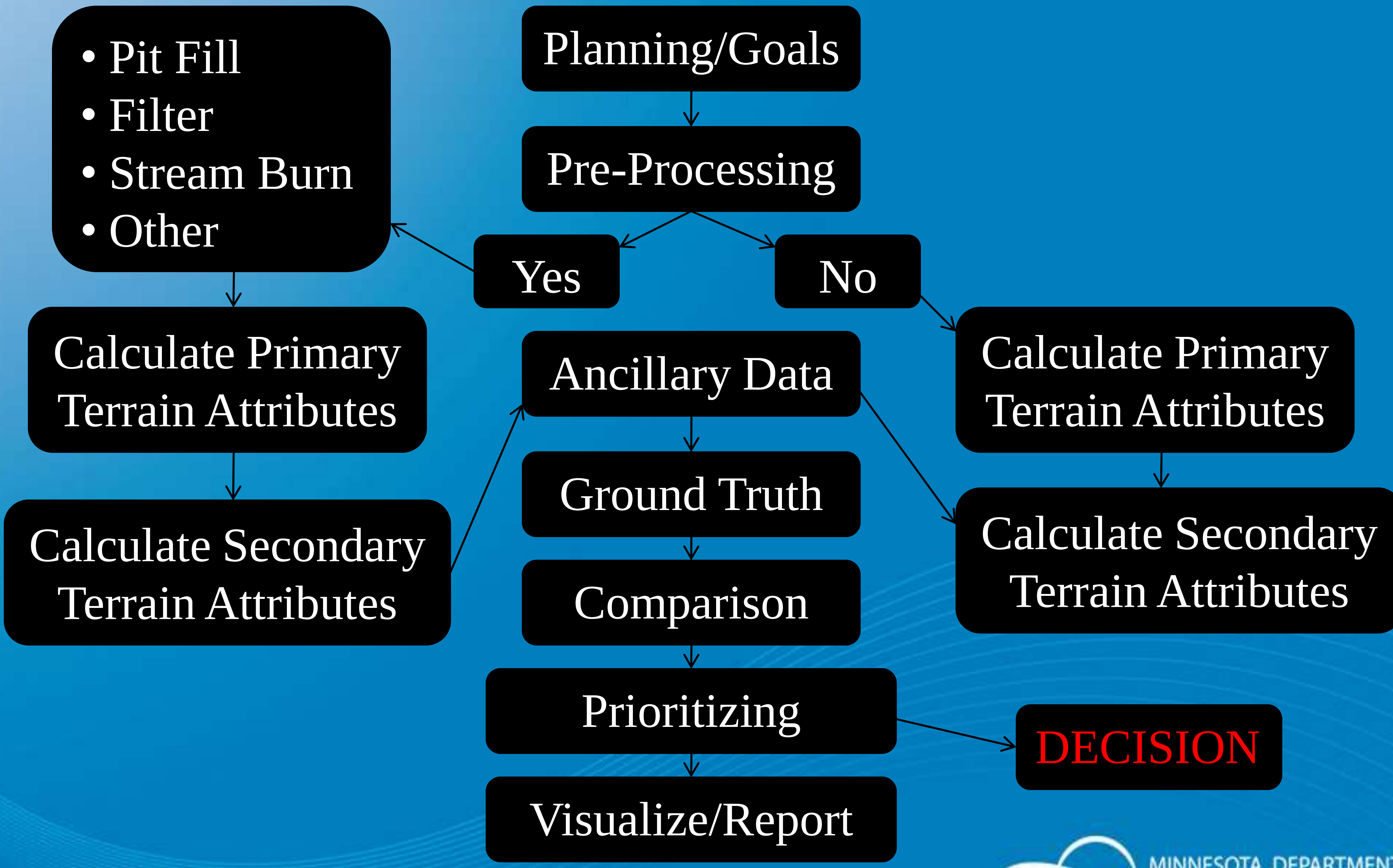
Applying Terrain Analysis to Conservation



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Terrain Analysis Caveats/Limitations

- Same limitations as LiDAR data in general
  - Cost
  - File Size/Computing Power
  - Expertise/Training
  - Pertains to surface flow only
- Terrain analysis does NOT
  - Replace local knowledge or field work
  - Transfer well to non-like landscapes when comparing terrain attribute values
  - Differentiate between man-made and “natural” structures

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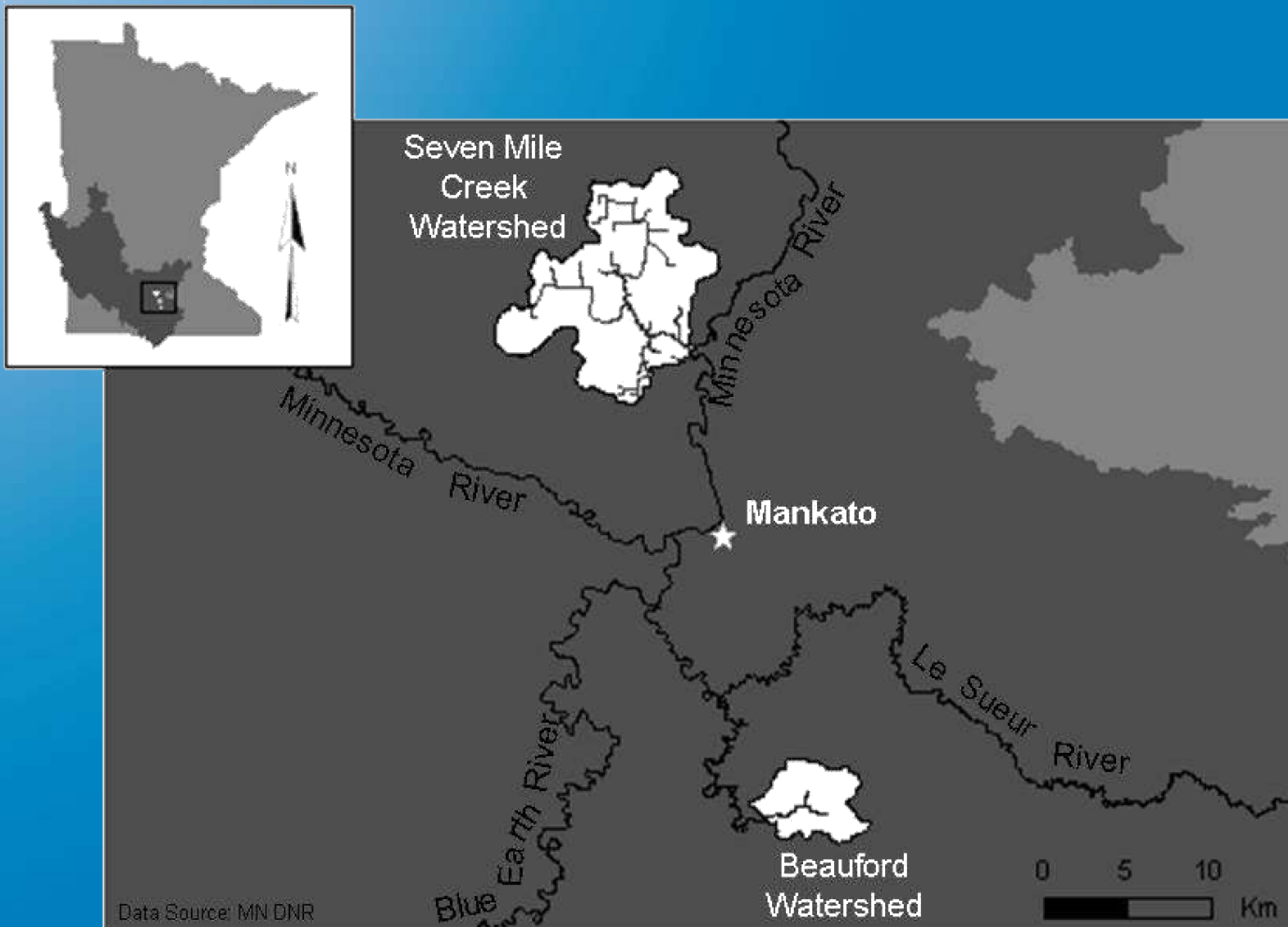
Precision Conservation Examples

Minnesota River Basin



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MRB Example

- David Mulla, Ph.D., Jake Galzki, and Joel Nelson (Department of Soil, Water, and Climate University of Minnesota)
- Objective is to develop a tool that uses terrain attributes to identify critical source areas vulnerable surface water runoff
  - 3m LiDAR-derived DEM: Beauford Ditch Watershed (Blue Earth County) and Seven Mile Creek Watershed (Nicollet County)
  - Focus primarily on near-stream features in the UPLANDS

Critical Areas

- Two criteria:
- Accumulation of surface flow
- Hydrologic connection to surface waters

Overview of Methods

- Calculated a suite of primary and secondary terrain attributes in the pilot watersheds
- Conducted a field survey to relate terrain attributes to critical source features in the field
- Identified terrain attributes that are of greatest use and used statistics to define threshold values

Field Surveys

- Handheld Pocket PC with WAAS GPS
- Field Mapping Software
- Tape Measure
- Digital Camera
- Compass
- Log book

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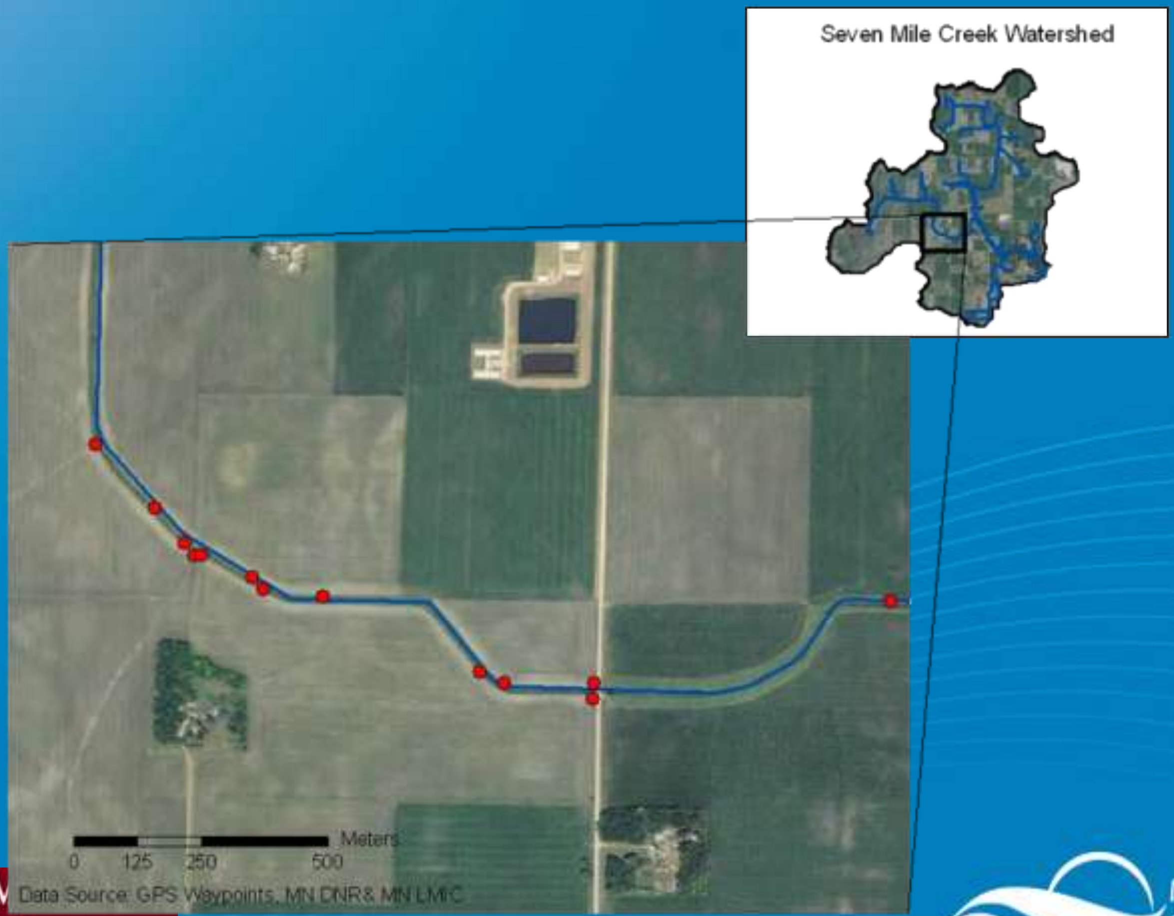
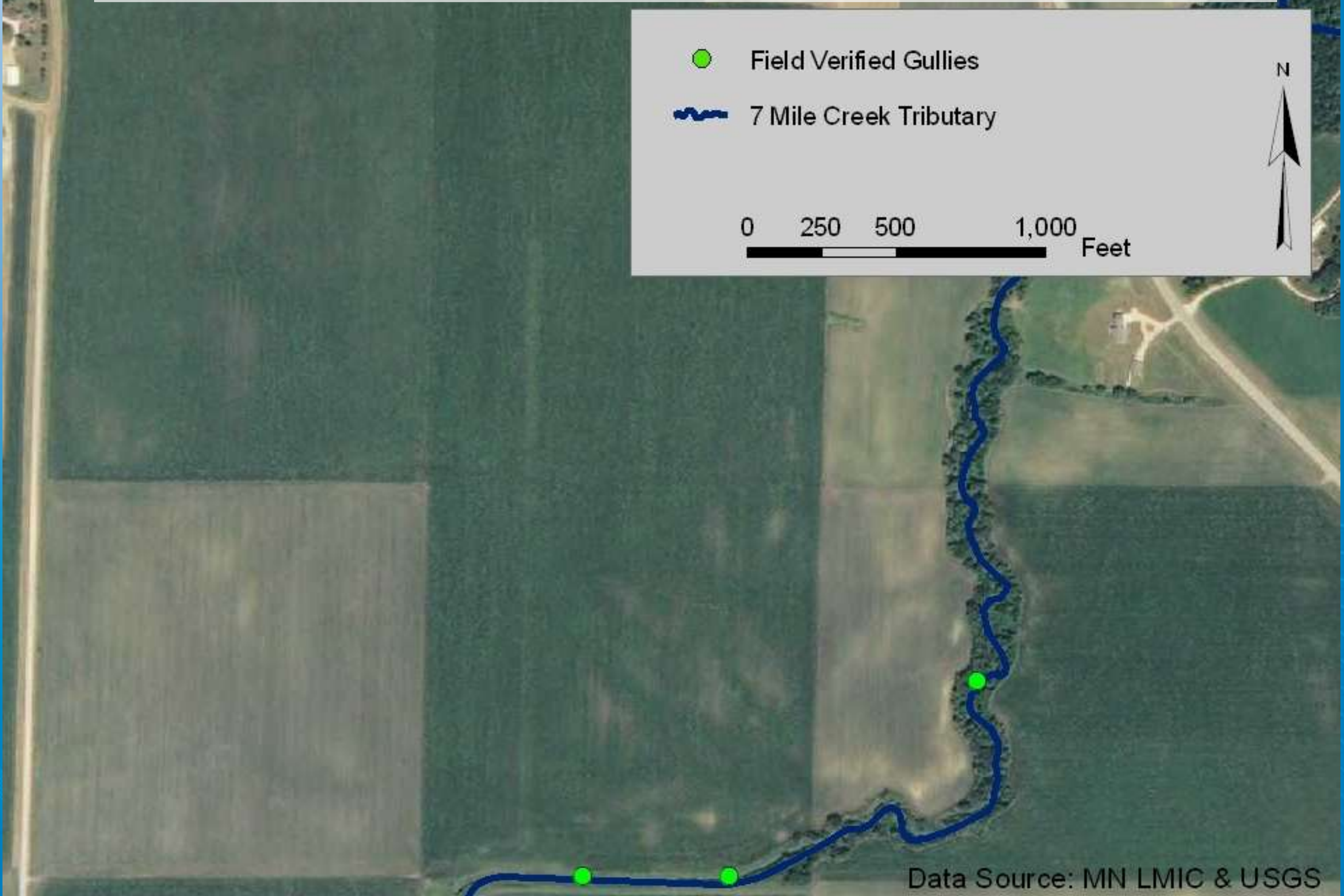
Methods

- Survey yielded GPS shapefile of points with associated field recorded attributes



Example: Using Flow Accumulation to Identify Gullies
Seven Mile Creek Watershed (Nicollet County)



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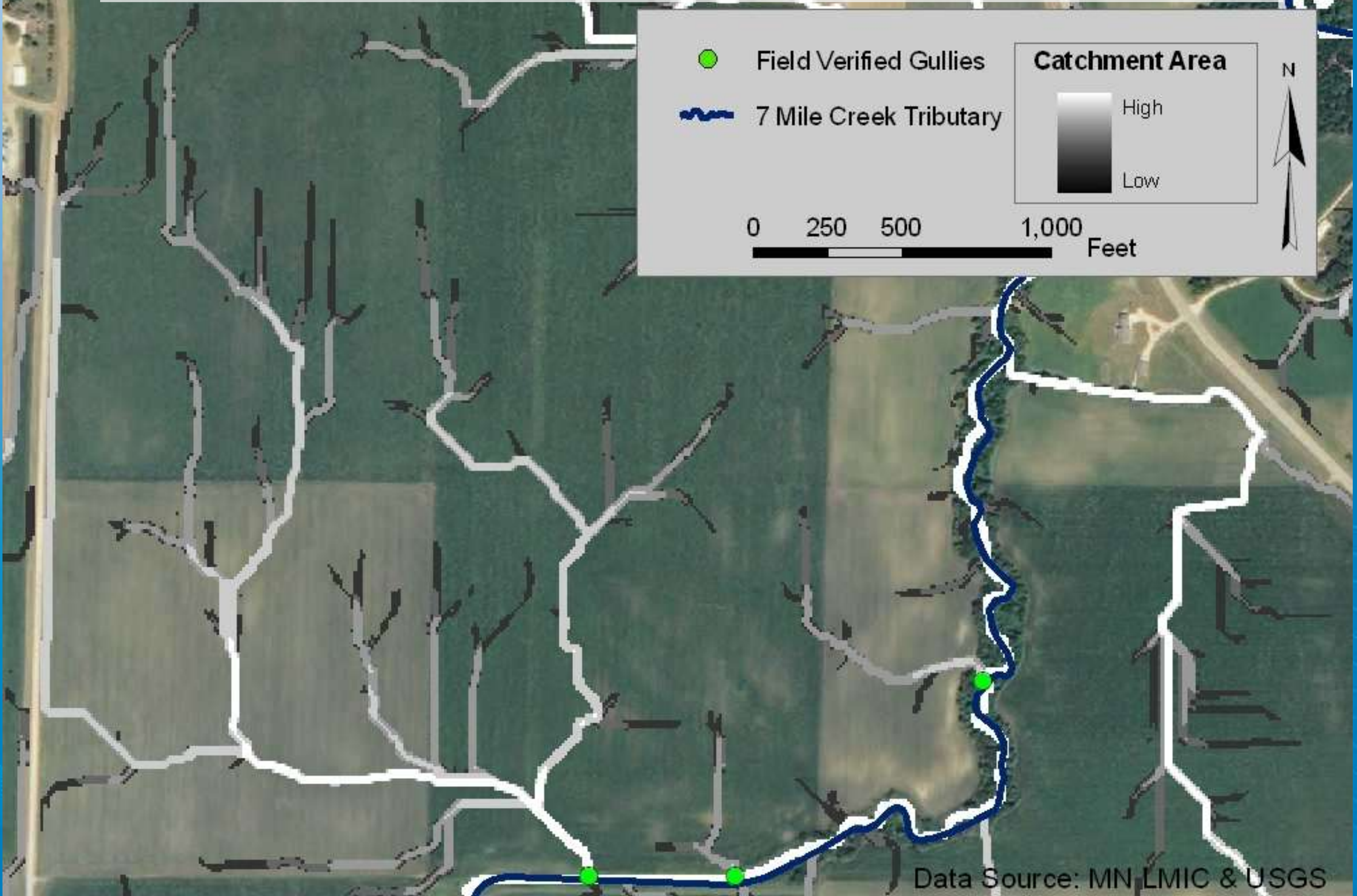

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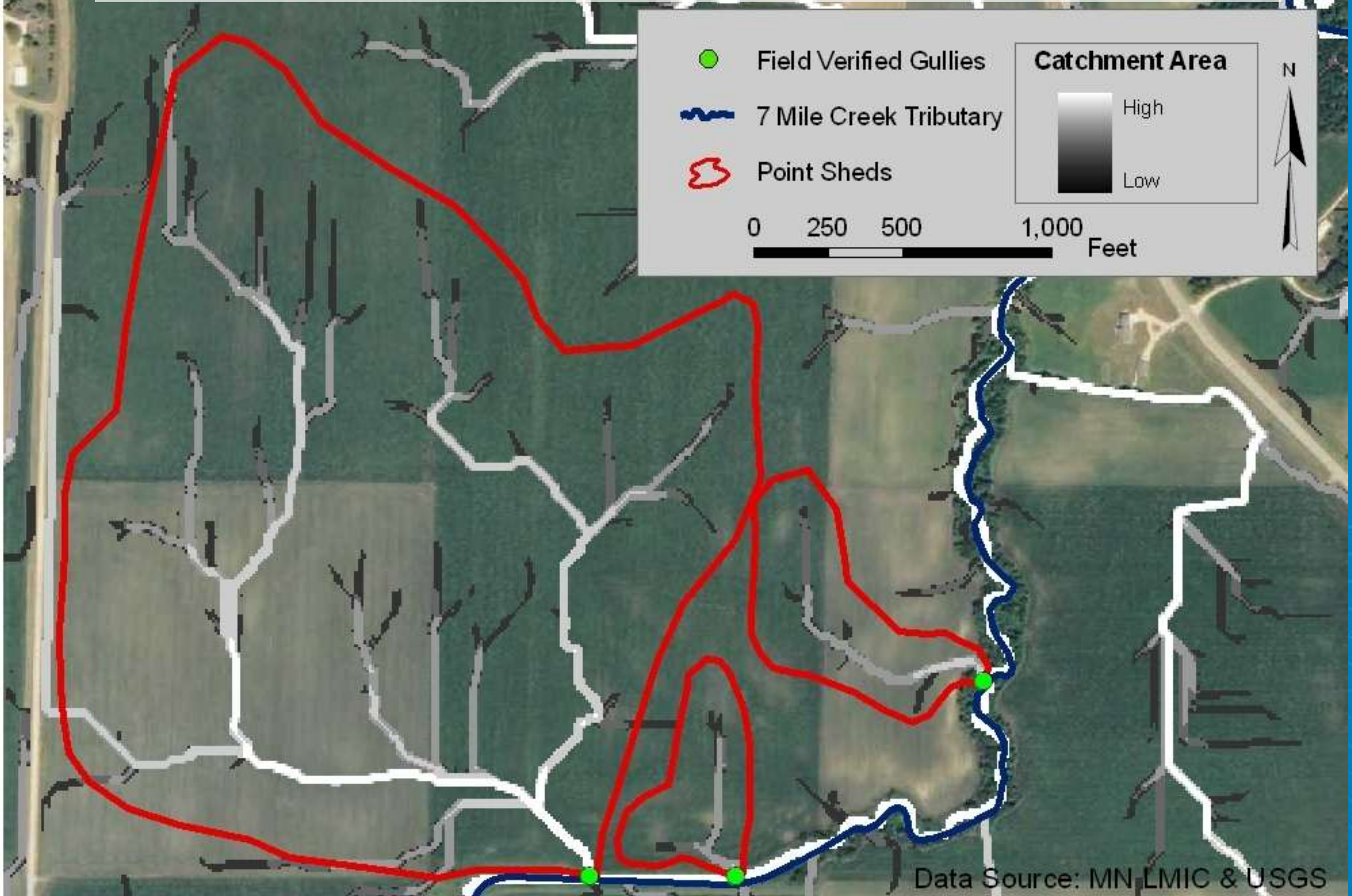
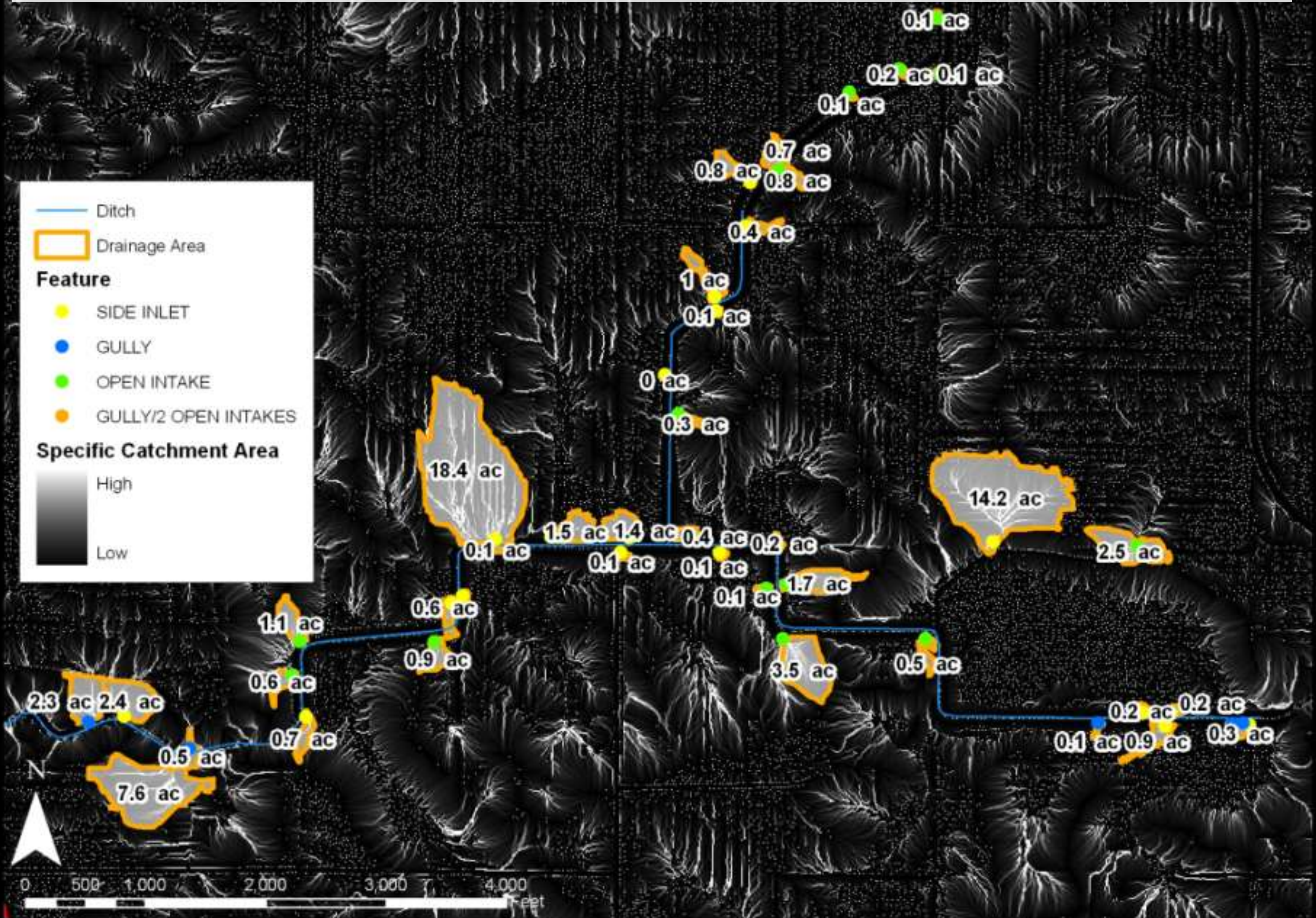


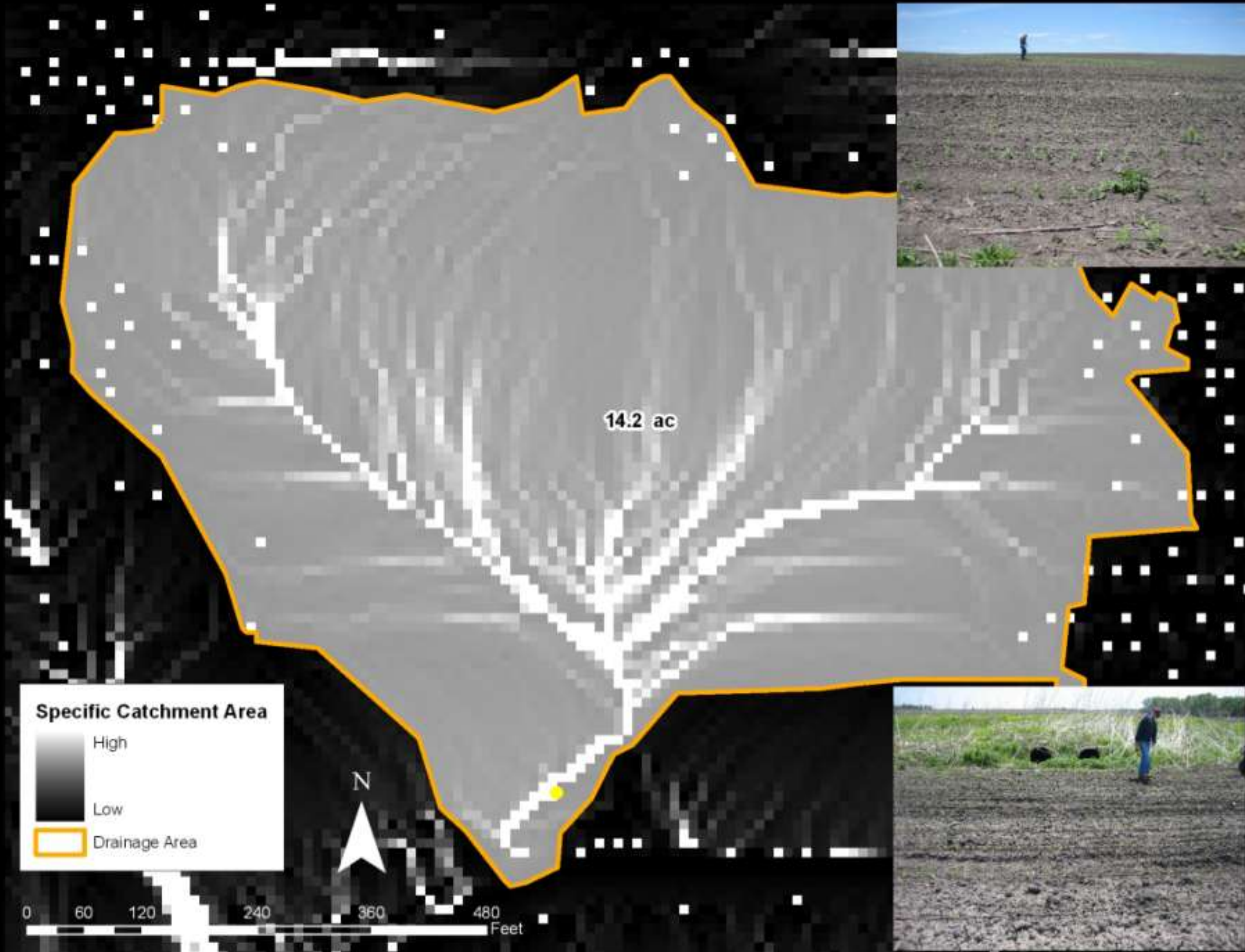
Courtesy of the Brown, Nicollet, Cottonwood Water Quality Board

Example: Using Flow Accumulation to Identify Critical Source Areas

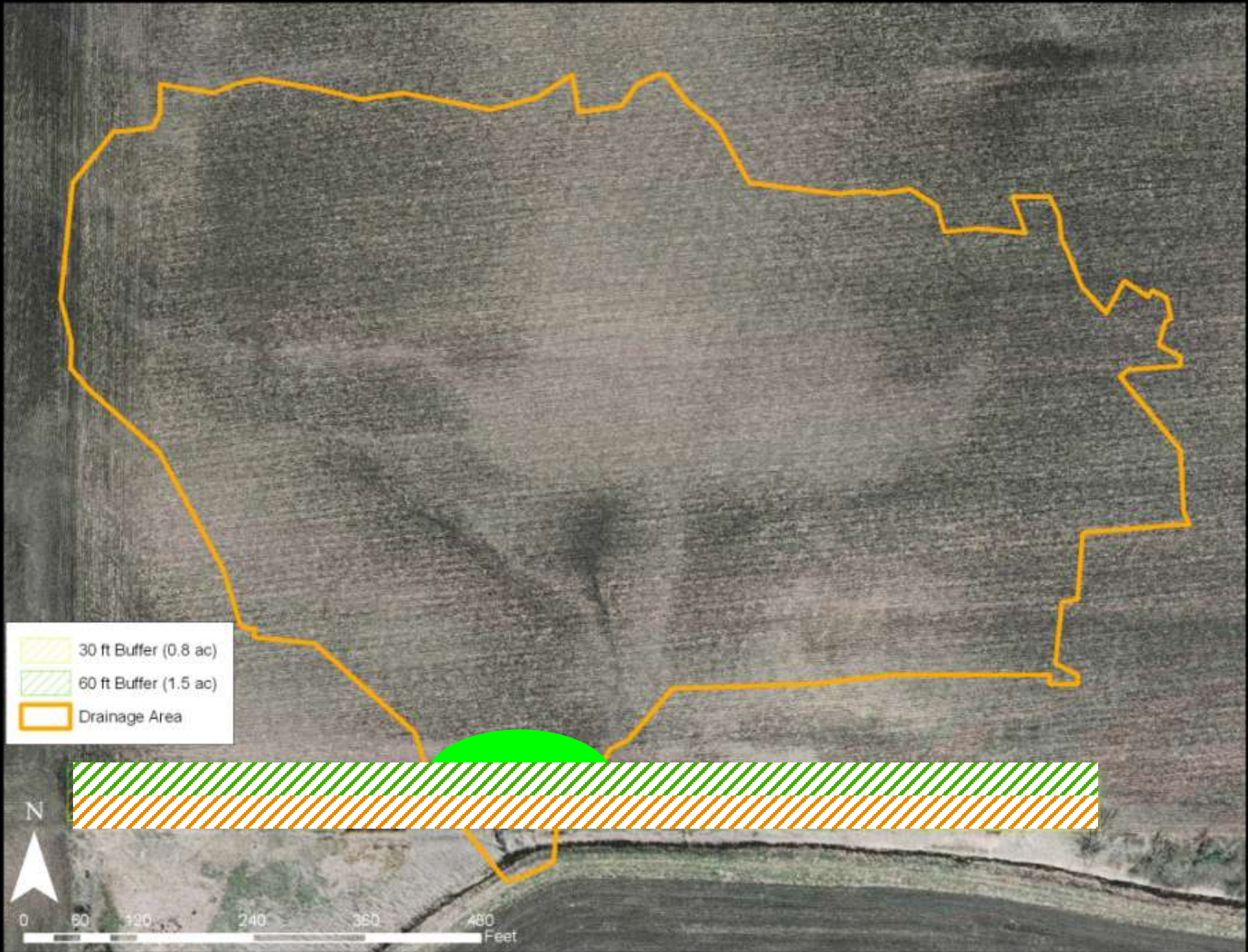
Beauford Watershed (Blue Earth County)

Example: Using Flow Accumulation to Identify Critical Source Areas
Beauford Watershed (Blue Earth County)

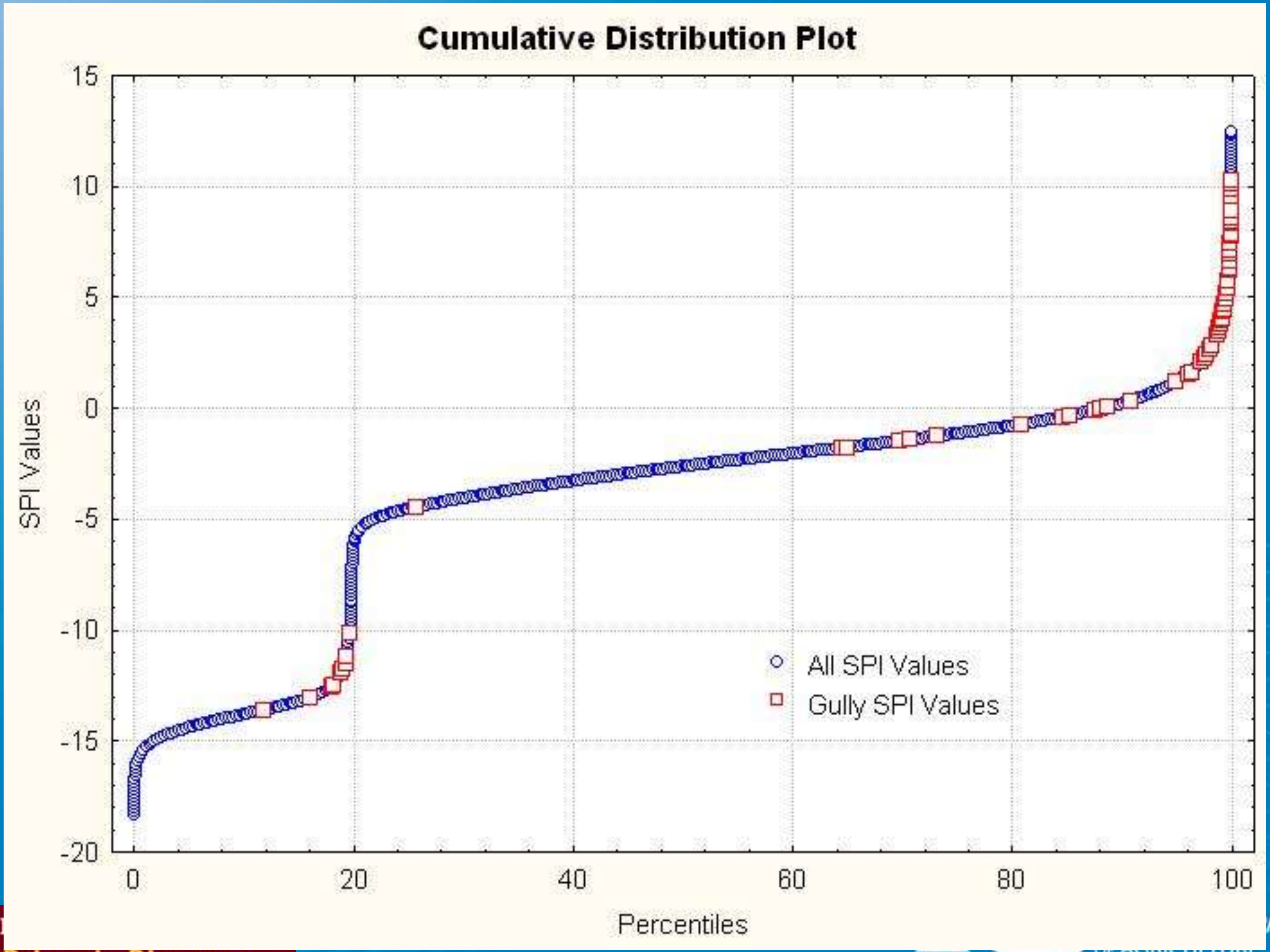




14.2 ac
Specific Catchment Area
High
Low
Drainage Area
N
0
60
120
240
360
480
Feet


30 ft Buffer (0.8 ac)
60 ft Buffer (1.5 ac)
Drainage Area
N
0
60
120
240
360
480
Feet

Results


Cumulative Distribution Plot
SPI Values
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
Percentiles
All SPI Values
Gully SPI Values

Results

- Confirmed that ordinal size of a feature is related to SPI
- Values suggest that there is a relationship to the terrain attribute value and the magnitude of the erosion feature
- Water monitoring needed to confirm this relationship

Average Percentiles of SPI for Gullies in Seven Mile Creek Watershed
Summarized by SDP Score

SDP Score	Average Percentile of SPI
High (SDP = 3)	97.4
Moderate (SDP = 2)	83.8
Low (SDP = 1)	72.8

Average Percentiles of SPI for Side Inlets in Beauford Watershed
Summarized by Inlet Size

Side Inlet Size	Average Percentile of SPI
Large (24 - 36 inches)	98.9
Medium (14 - 18 inches)	93.3
Small (4 - 12 inches)	81

Validation Set

- Mapped features were compared to field surveyed points
- 65 of 83 gullies in the watershed were identified using the top 15% of SPI values.
- 31 of 32 largest gullies identified in the field were identified using the top 15% of SPI values.

Number of field verified features identified by the GIS based survey
Summarized by SDP score

	Identified	Not Identified	Total Present
SDP 3 Gully	31	1	32
SDP 2 Gully	17	5	22
SDP 1 Gully	17	12	29
Total*	65	18 (Type II Error)	83
No Feature	43 (Type I Error)		

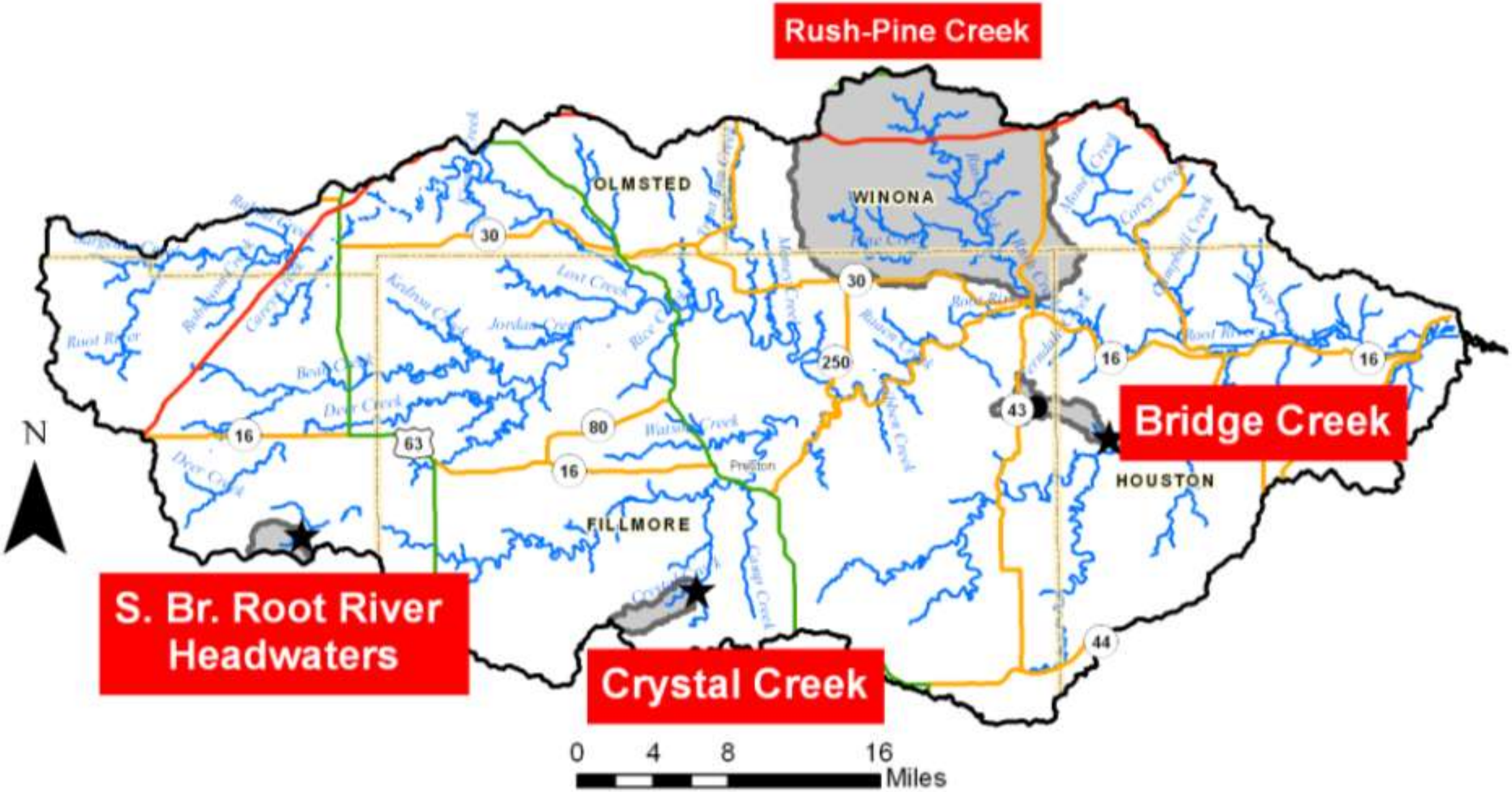
Cost Benefits of Terrain Analysis
Seven Mile Creek Watershed

- Walking survey took 10 days and about 300 labor hours with 3 people
- Total cost = $9,500 or about $413/ditch mile
- It is estimated that it would take about 10-12 years at a cost of about $100,000-$120,000 in labor to conduct the same survey for the rest of the County
- *Source: Brown Nicollet Cottonwood Water Quality Board*

Cost Benefits of Terrain Analysis
Seven Mile Creek Watershed

- LiDAR Based GIS survey completed in a matter of hours
- County-wide survey could be finished in a matter of weeks
- Majority of the largest contributing areas would be identified
- Temporal and financial requirements are a small fraction of the field based surveys

Root River Field to Stream Partnership



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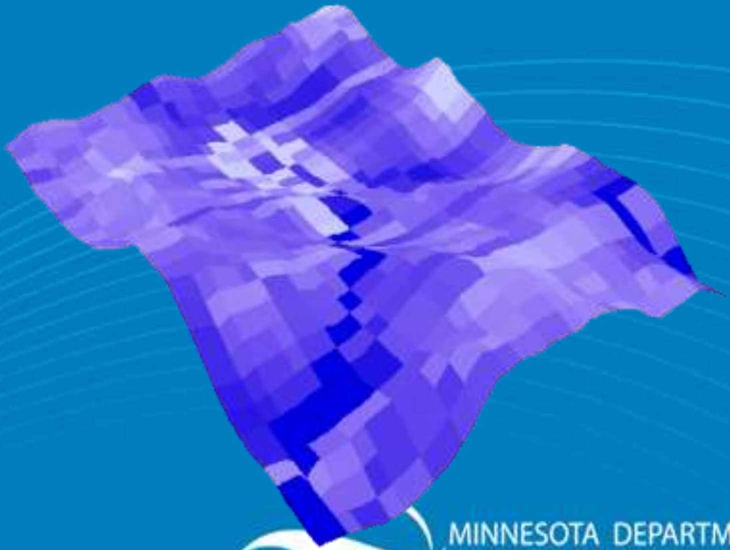
Activities

- Monitoring
  - Watershed Outlet
  - Edge-of-Field
  - Stream Reach Surveys
  - Bioavailable Phosphorus Evaluation
  - Sediment Fingerprinting
  - Groundwater/Vadose Zone
- Watershed Assessment Tools
  - Farm Management Surveys
  - Agronomic Assessments
  - Digital Terrain Analysis
- Evaluation of BMPs
  - Short-term: Edge of Field
  - Long-term: Watershed Scale



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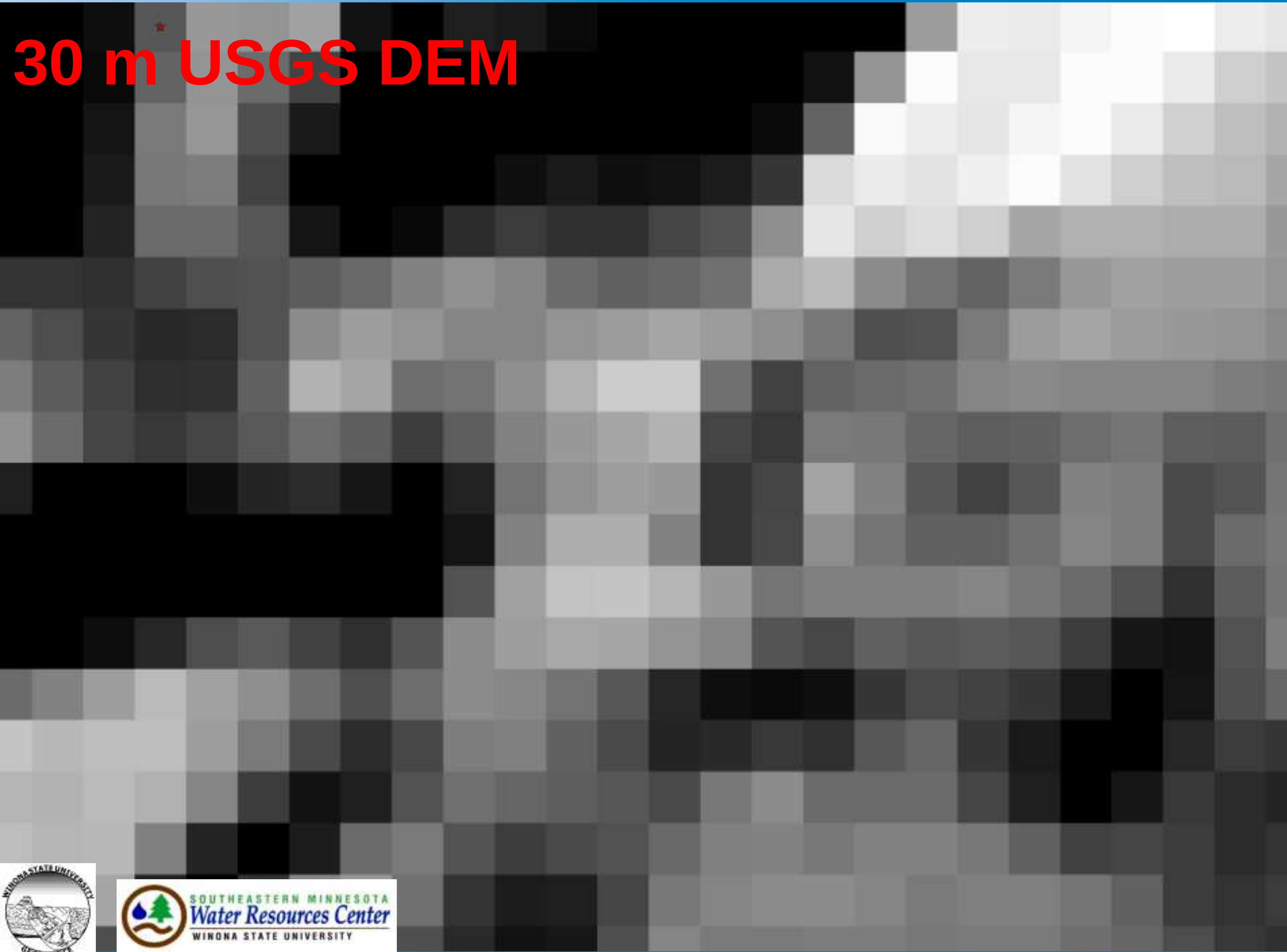
30 m USGS DEM



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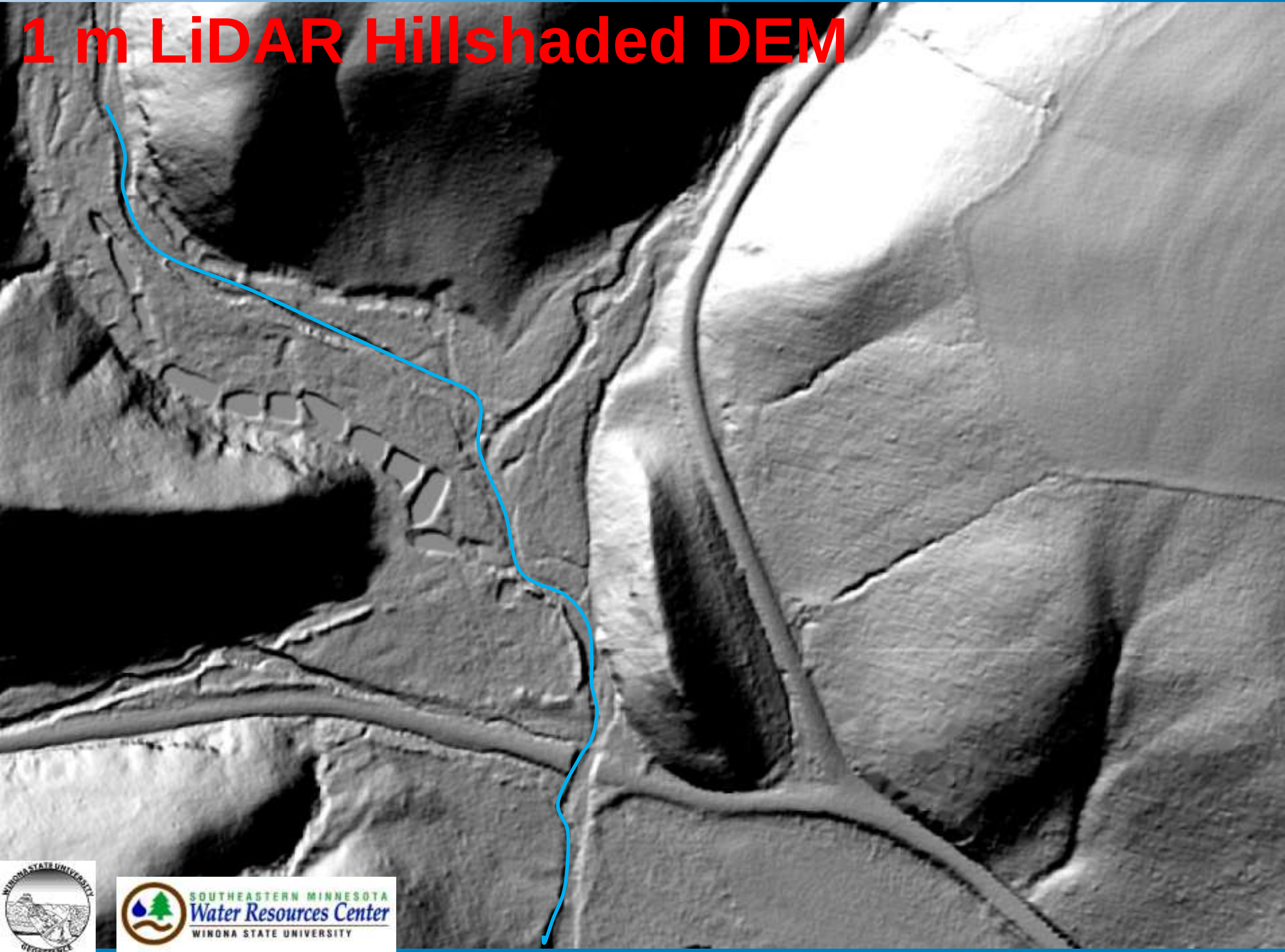
1 m LiDAR Hillshaded DEM



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Winona State University

Pictometry 8” Color

SOUTHEASTERN MINNESOTA
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1 m LiDAR Hillshaded DEM + Draped Photo

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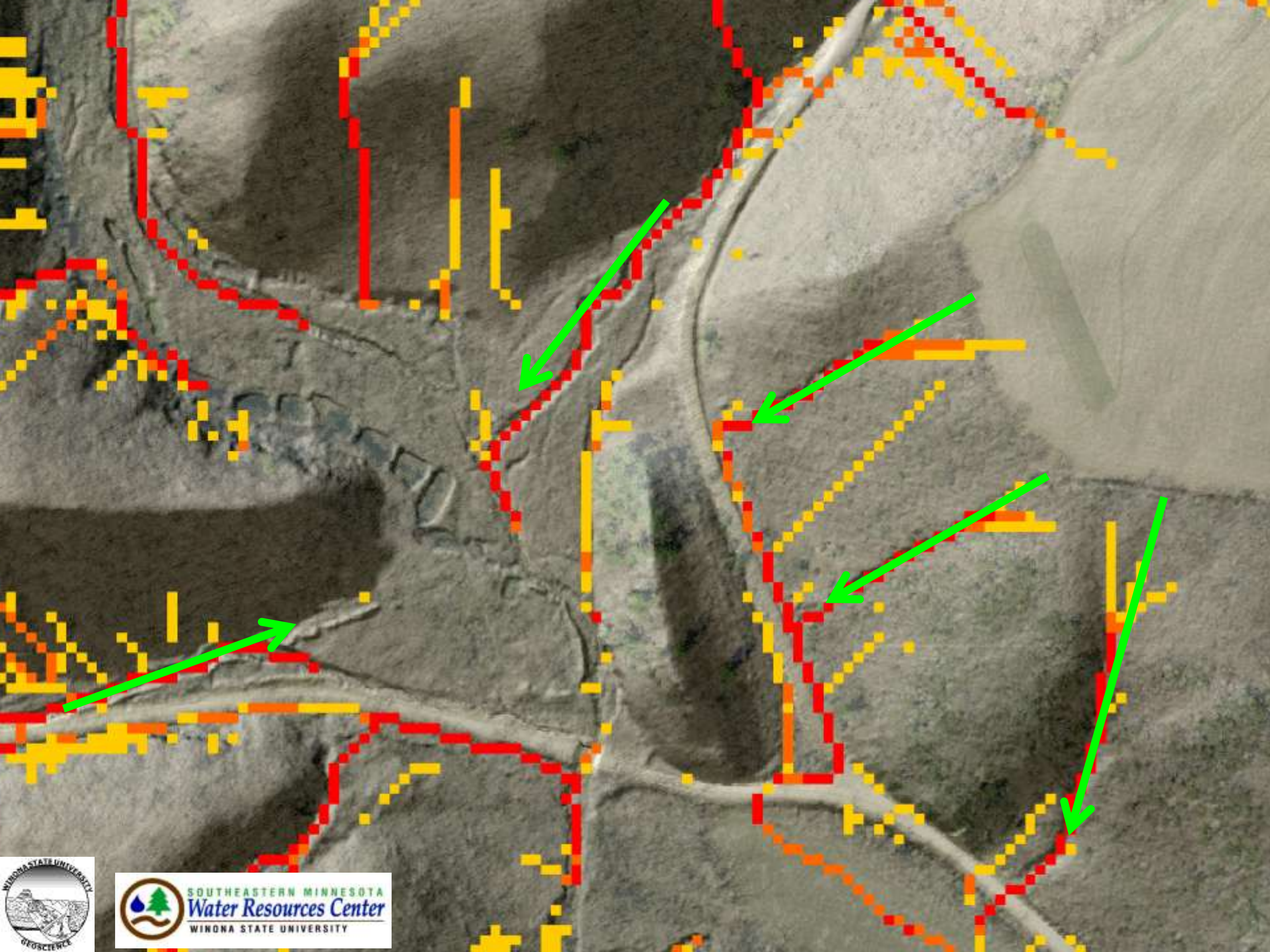
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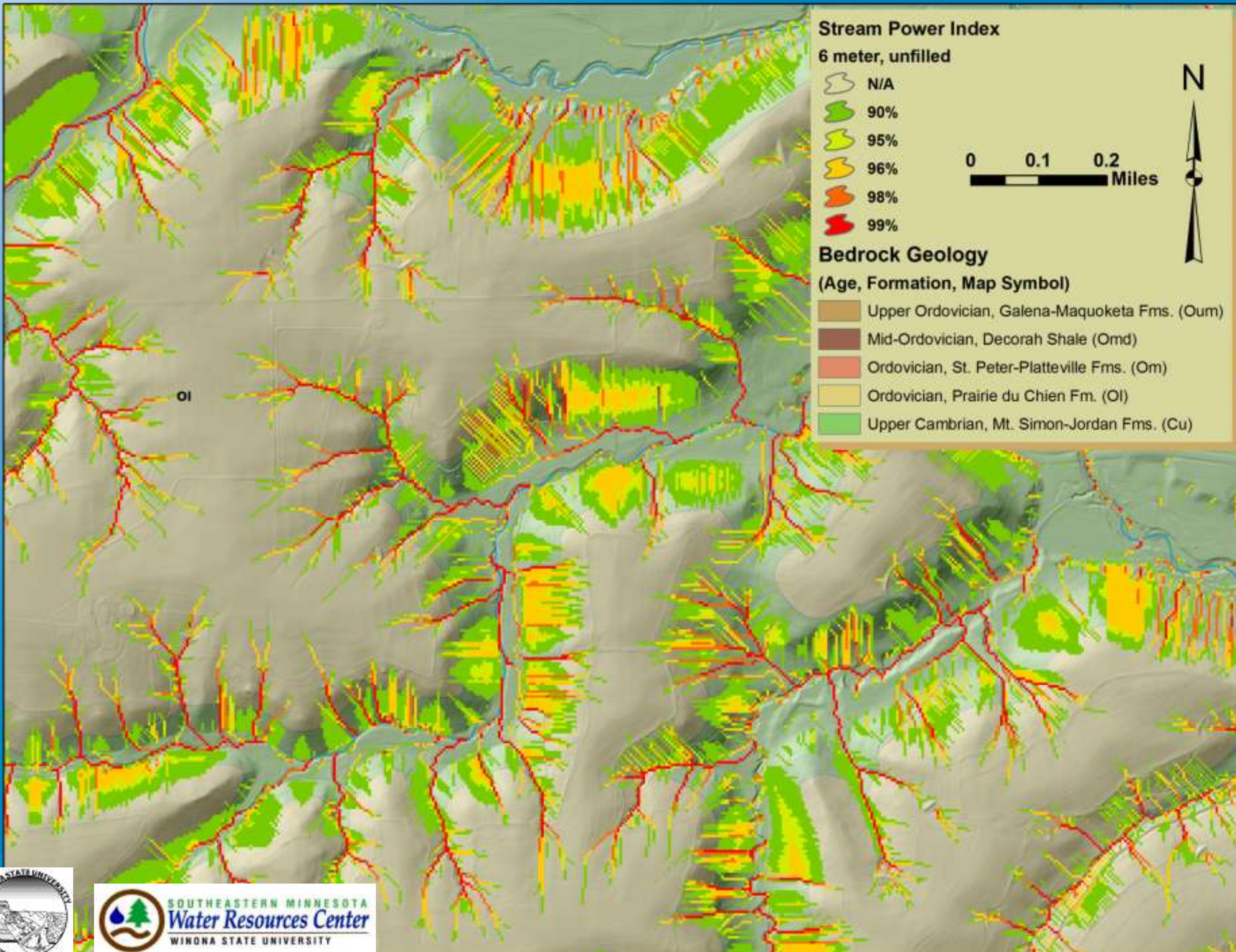
N
Omd
Om
Ol
Cu
12-Digit HUCs
Stream Power Index
6 meter, unfilled
N/A
90%
95%
96%
98%
99%
Bedrock Geology
(Age, Formation, Map Symbol)
Upper Ordovician, Galena-Maquoketa Fms. (Oum)
Mid-Ordovician, Decorah Shale (Omd)
Ordovician, St. Peter-Platteville Fms. (Om)
Ordovician, Prairie du Chien Fm. (Ol)
Upper Cambrian, Mt. Simon-Jordan Fms. (Cu)
0 1 2 3
Miles
Southeastern Minnesota Water Resources Center
Winona State University
Minnesota Department of Agriculture



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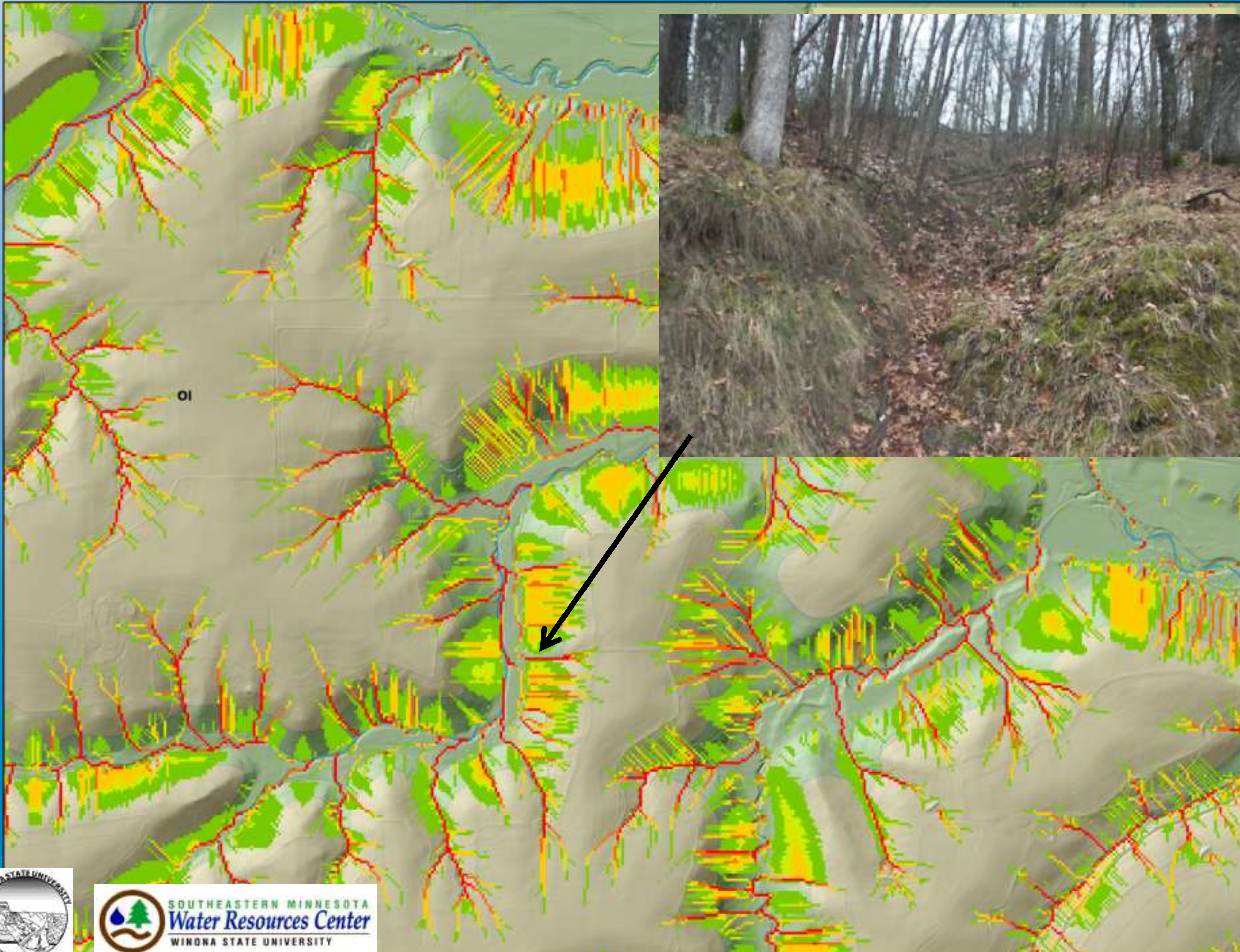

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Water Resources Center
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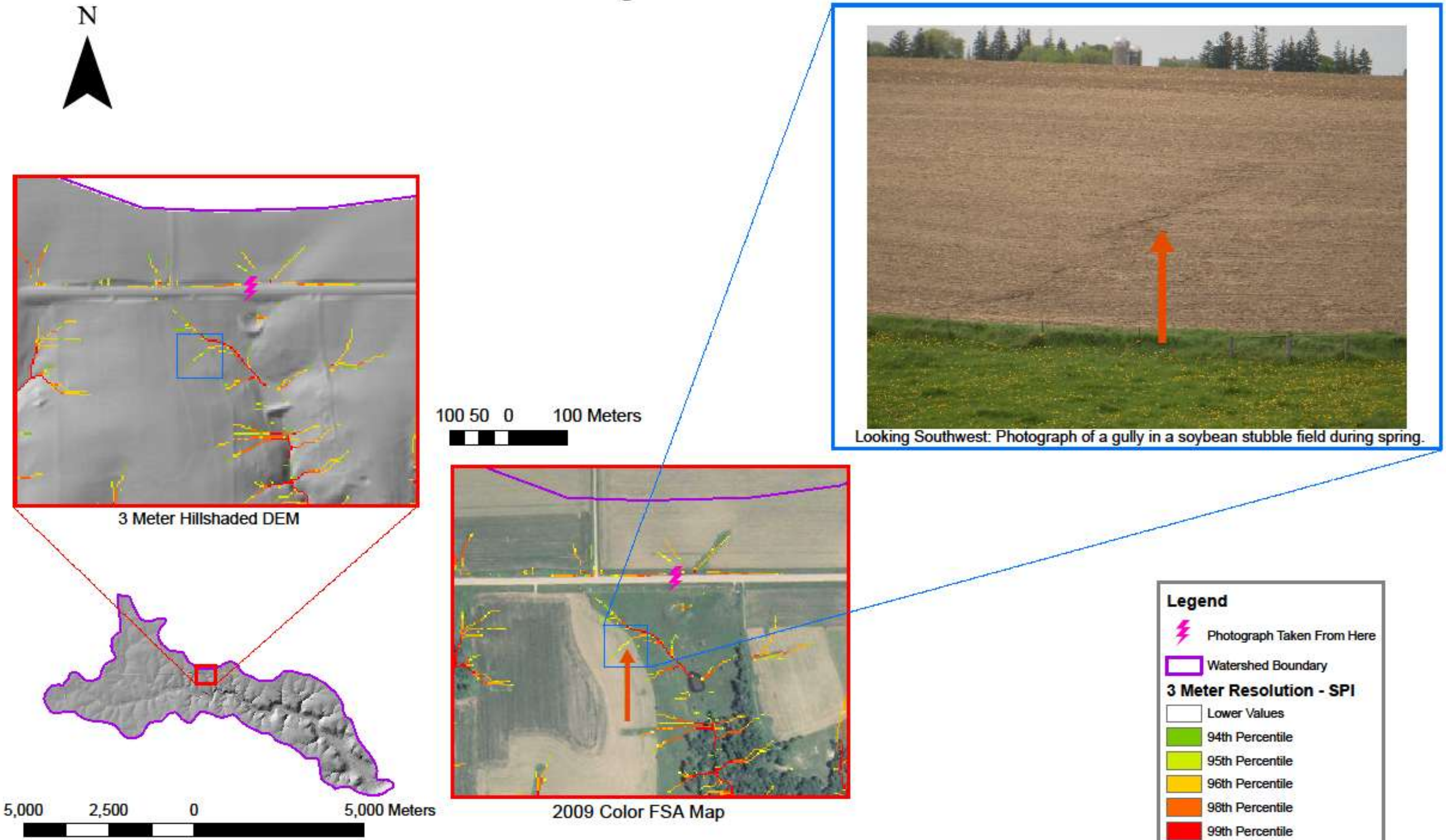
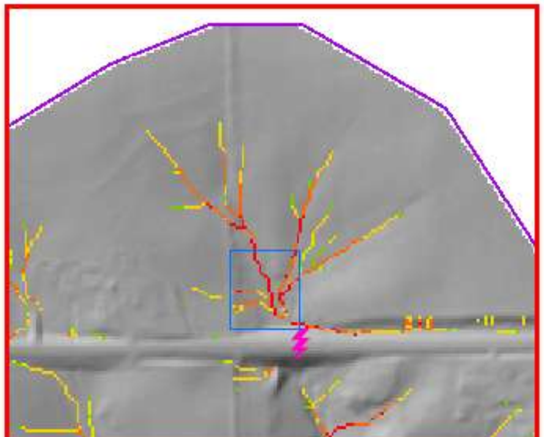
Field Verification of a Gully in the Bridge Creek Watershed Using a 3 Meter DEM



Field Verification of Grassed Waterway Effectiveness in the Bridge Creek Watershed Using a 3 Meter DEM



3 Meter Hillshaded DEM

100 50 0 100 Meters

Looking Northwest: Photograph of a grassed waterway and outlet area showing no gully formation in an area where high SPI is present.

2009 Color FSA Map

5,000 2,500 0 5,000 Meters

Legend

Photograph Taken From Here

Watershed Boundary

3 Meter Resolution - SPI

Lower Values

94th Percentile

95th Percentile

96th Percentile

98th Percentile

99th Percentile

http://www.mda.state.mn.us/protecting/cleanwater/allocations/techprojects/precisionconsinit.aspx

Clean Water Fund / Precision Conservation Initiative

Precision Conservation: Piloting Local Use of Tools for Targeting Clean Water Implementation

The goal of this initiative is to disseminate recently developed high-resolution GIS-based terrain analysis modeling techniques to conservation professionals who work on locally-led water cleanup and protection efforts. MDA developed the terrain analysis techniques in a previous Clean Water Legacy funded project to provide a more scientific basis for identifying and prioritizing critical areas of the landscape, i.e., places where conservation practices will be more effective at restoring and protecting water quality.

Phase I consists of training to help natural resource analysts understand when, why and how to use terrain analysis modeling as a tool for targeting locally-led water quality efforts. Three workshops have been held and more are planned.

- **TAM Workshops Summary** – overview of first three workshops (PDF: 360 KB/1 page)
- **TAM Workshop Agenda** – sample workshop agenda (PDF: 316 KB/1 page)
- **TAM Workshop Presentation** – presentation slides (PDF: 2,043 KB/35 pages)
- **TAM Workshop Manual** – hands-on exercises (PDF: 648 KB/20 pages)

Phase II will produce information about the real-world applicability of terrain analysis modeling for watershed-based clean water implementation projects in Minnesota. For example, how ready and able are local governments to undertake this kind of modeling and interpret the results? What products developed through terrain analysis modeling will be most helpful in facilitating targeted implementation (e.g., better estimates of the number of acres needing treatment and the associated costs; presentation-quality maps designed to better communicate the scientific basis for targeting decisions to landowners)? MDA will partner with watershed organizations, the University of Minnesota and others to explore questions of this nature and develop sample products to share with local project leaders throughout the state.

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Conclusions

- Terrain analysis can be a very fast and effective tool to locate critical areas
- Terrain attribute values are related to ordinal size of erosional features
  - Conservation efforts can target most severe erosion risks
  - Targeting can be matched to financial constraints with a high likelihood of capturing the largest features
  - Efficiency of all resources involved are maximized
- These methods are easy to employ and can serve as a valuable use of newly acquired LiDAR data

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Questions?

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