Identifying Critical Portions of the Landscape for Water Quality Protection Using Terrain Analysis

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Clean Water Funding Initiatives

- Passage of the constitutional amendment provides badly needed funding for protection, restoration and enhancement of impaired waters and damaged wildlife habitat
- Funding from the Clean Water Fund should be spent on the most critical landscapes and sources of water quality degradation
- There is a pressing need for tools to identify these critical areas

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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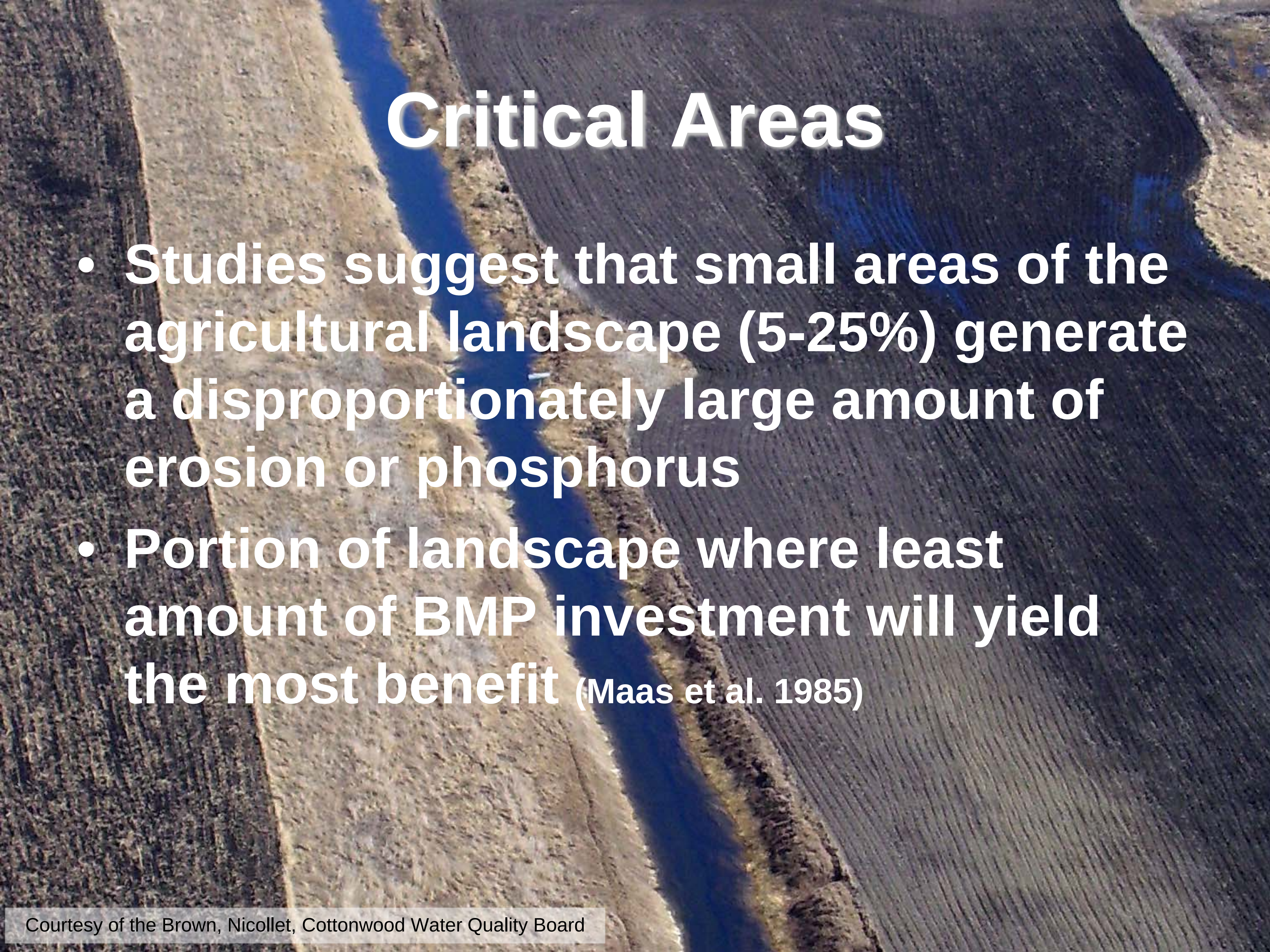
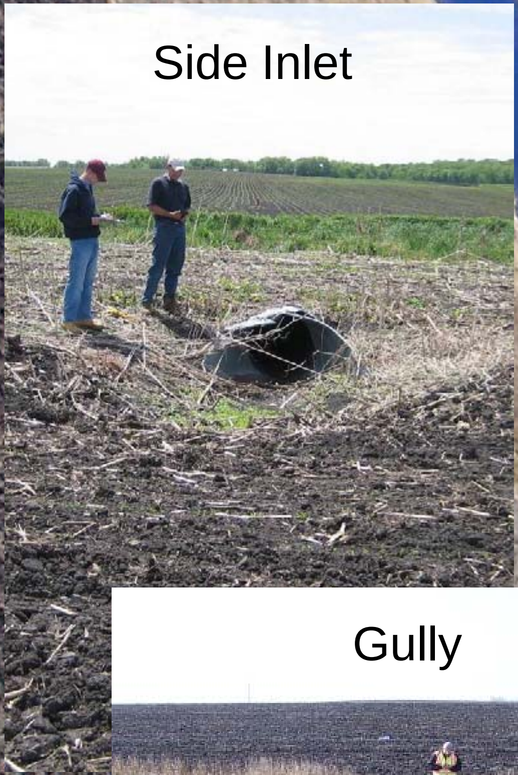
Critical Areas

- **Studies suggest that small areas of the agricultural landscape (5-25%) generate a disproportionately large amount of erosion or phosphorus**
- **Portion of landscape where least amount of BMP investment will yield the most benefit** (Maas et al. 1985)



Courtesy of the Brown, Nicollet, Cottonwood Water Quality Board

Critical Areas



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

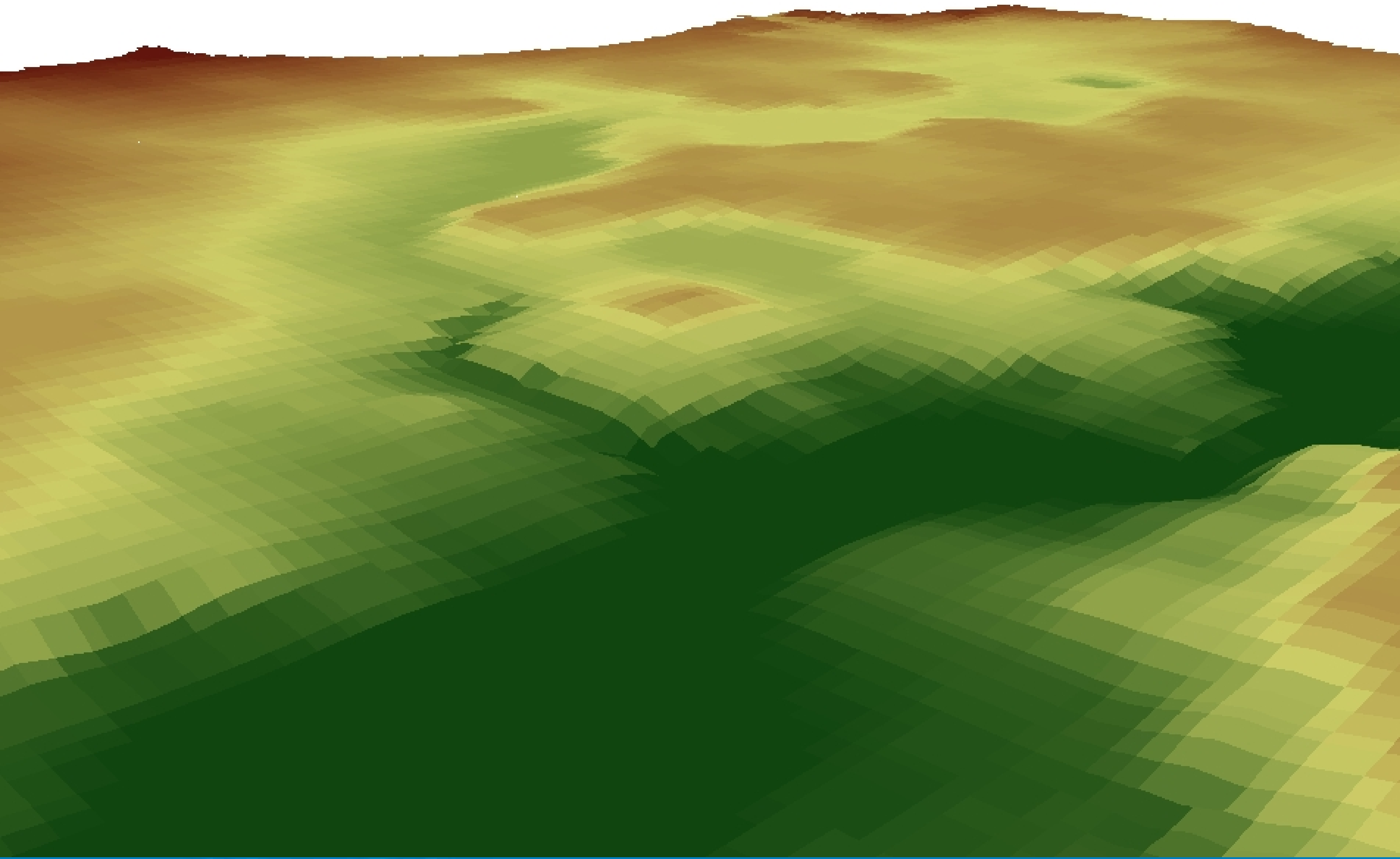
Critical Areas: Identification

- Defining critical areas is a challenge due to the hydrologic complexity and natural variability that occurs across the landscape
- Terrain analysis of Digital Elevation Models (DEMs) may be the key to defining critical areas
- LiDAR data can greatly enhance our ability to identify the critical areas

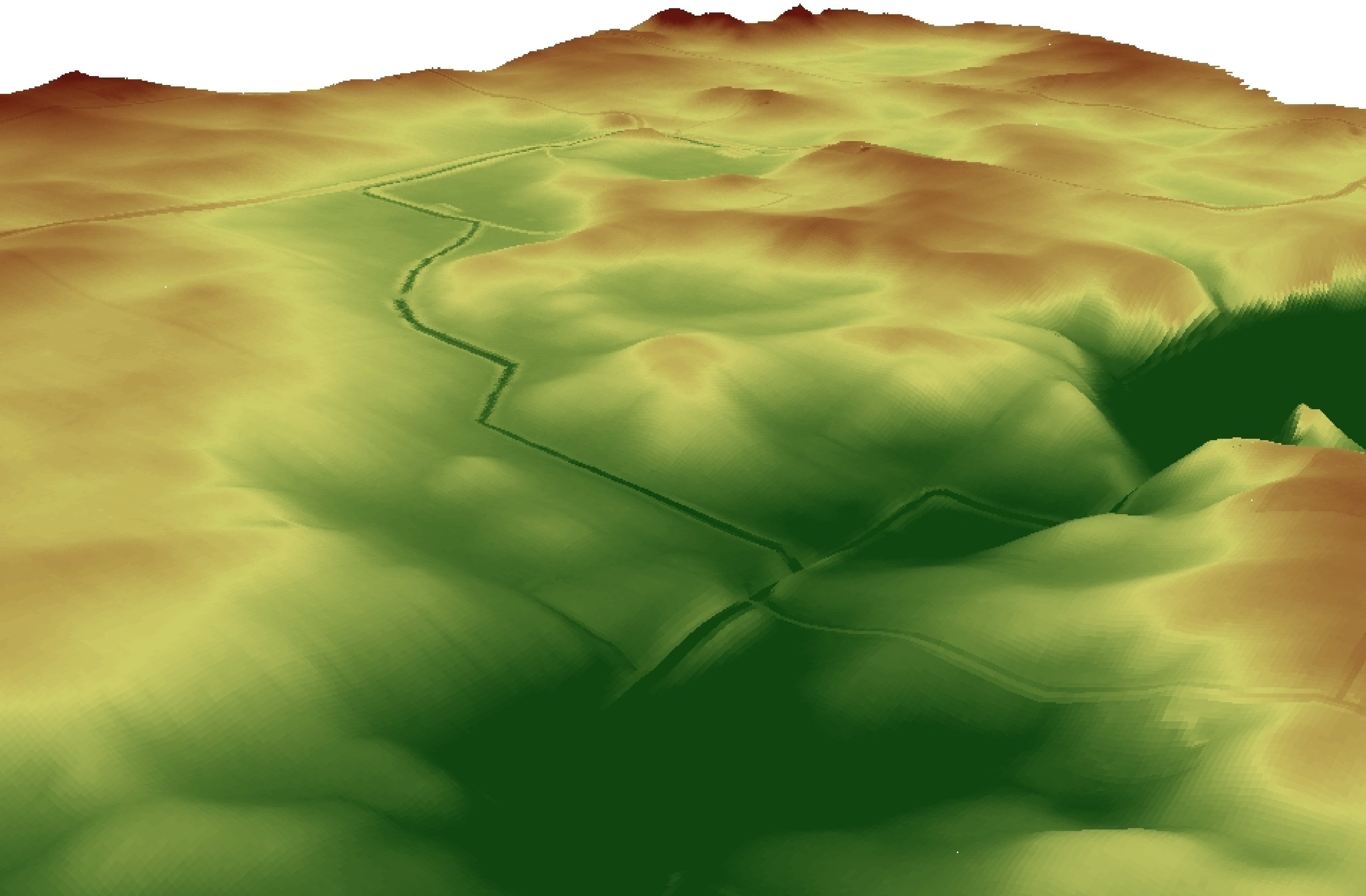
The Future of Elevation Data: Lasers

- Terrain analysis has been used for decades on coarse scale data
- LiDAR has greatly improved the resolution of elevation data

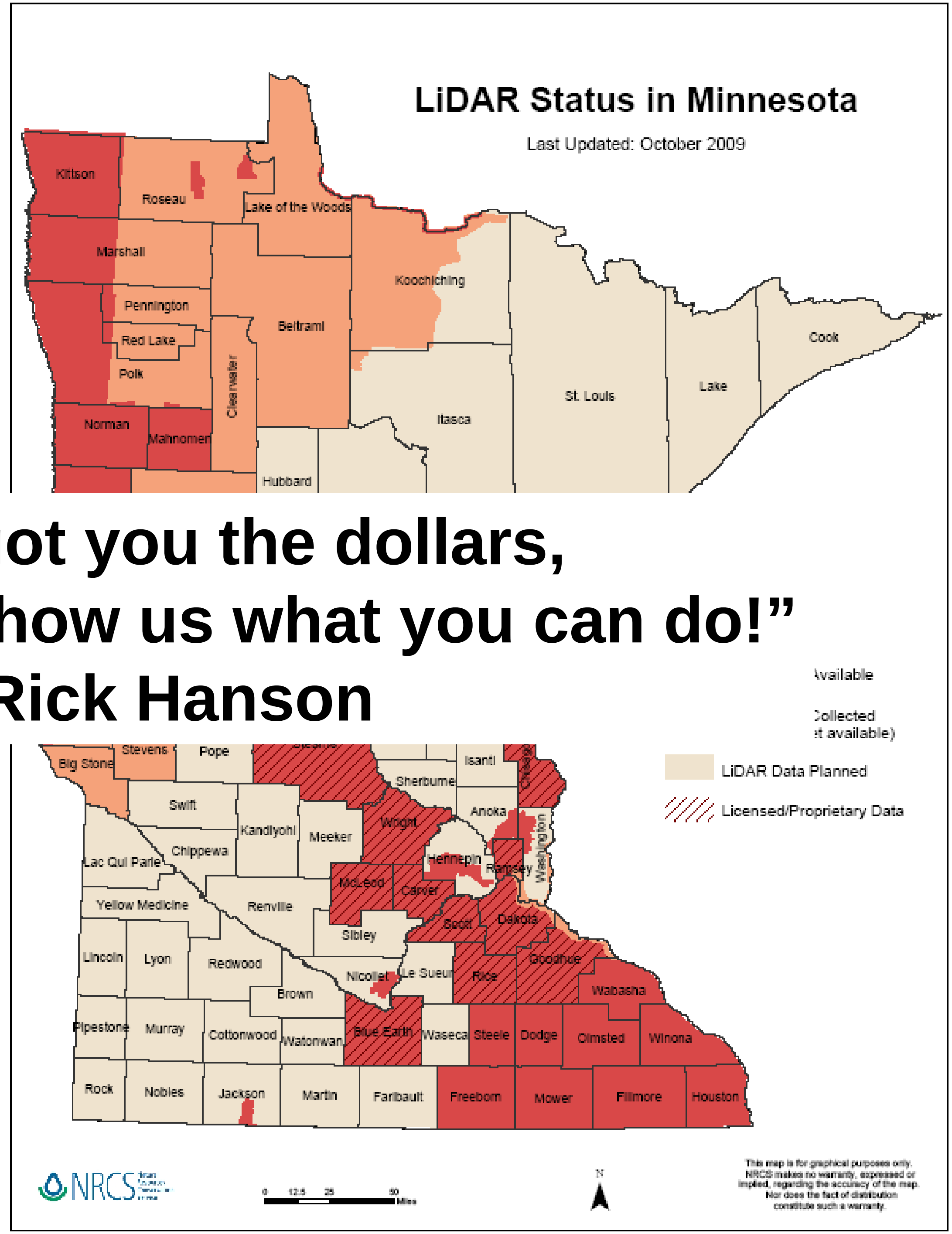
USGS 30 meter Elevation data



LiDAR 3 meter Elevation data



- 25 Minnesota counties currently have LiDAR data available
- Statewide LiDAR a b Clean Water Fund ($5.6 million)
- To be completed in 2012



“The legislature got you the dollars, now go out and show us what you can do!”
- Representative Rick Hanson

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Terrain Analysis - DEM

- Use of a DEM to model the landscape
- Quantitative approach to representing features on the landscape
- Accurately characterize large areas quickly
- Describe, analyze, and interpret any topographically-related feature: soils, vegetation, wildlife, etc

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Characteristics of Digital Terrain Analysis

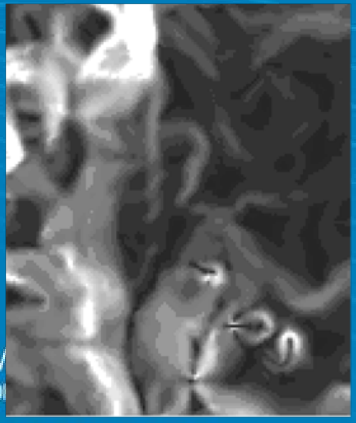
- Sacrifices physical sophistication for simple calculations describing soil moisture patterns
- Input requirements readily accessible and appropriate for the precision with which many management questions need to be and can be answered (Barling et al., 1994)
- Several studies have demonstrated the use of topographic indices to characterize the spatial distribution of soil moisture and soil mapping components controlled by soil hydrology (Bell et al., 1994; Thompson et al., 1998; Fried et al., 2000)

Digital Terrain Analysis Overview Example

Point Elevations with GPS

DEM

Terrain Attributes



Spatial Interpolation

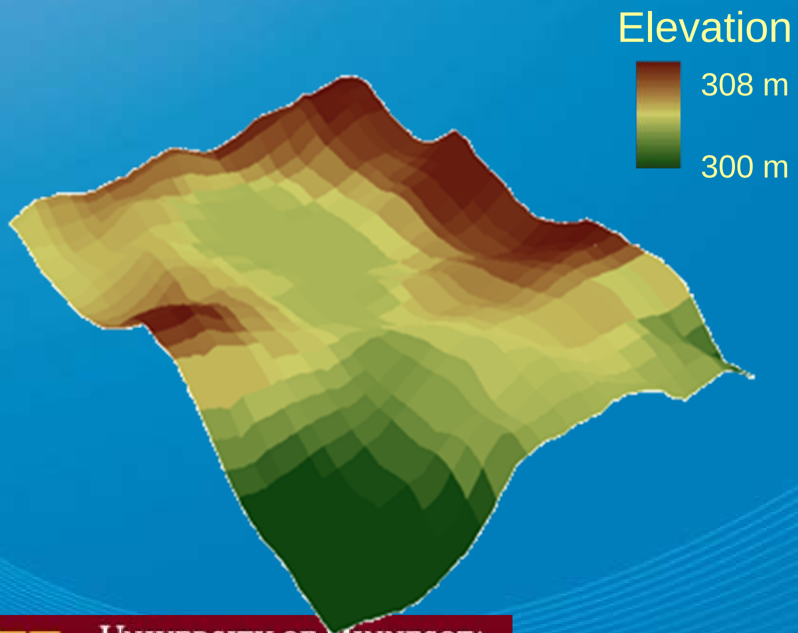
Attribute Calculation

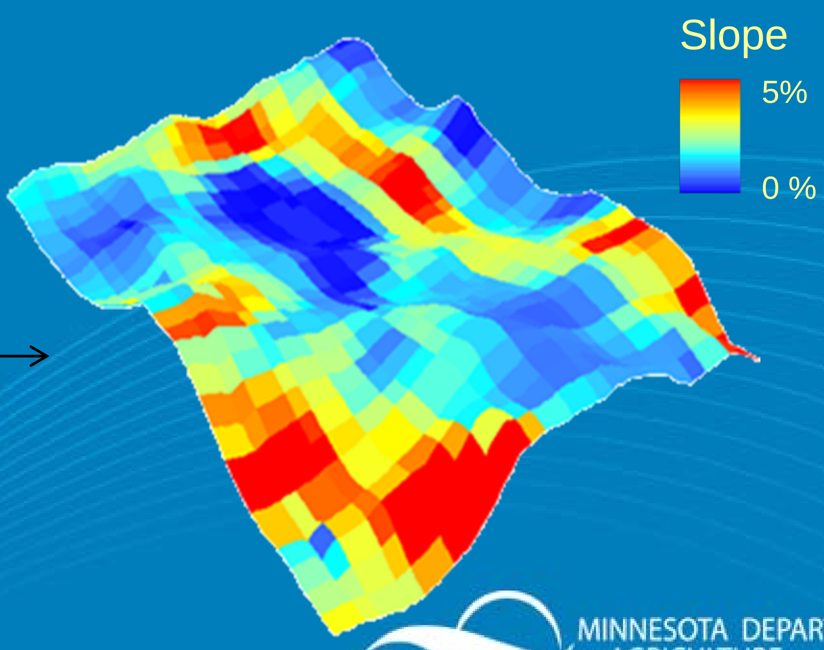
Terrain Attributes

- Divided into primary and secondary (compound) attributes
- Primary attributes are calculated directly from the elevation data
  - Examples: Aspect, slope, catchment area, profile curvature, etc
- Compound attributes involve combinations of primary attributes and are indices that describe the spatial variability of specific process occurring n the landscape such as the potential for sheet erosion (Moore et al., 1991; Wilson and Gallant, 2000)
  - Examples: Wetness index, Stream power index, etc

Terrain Attributes: Slope

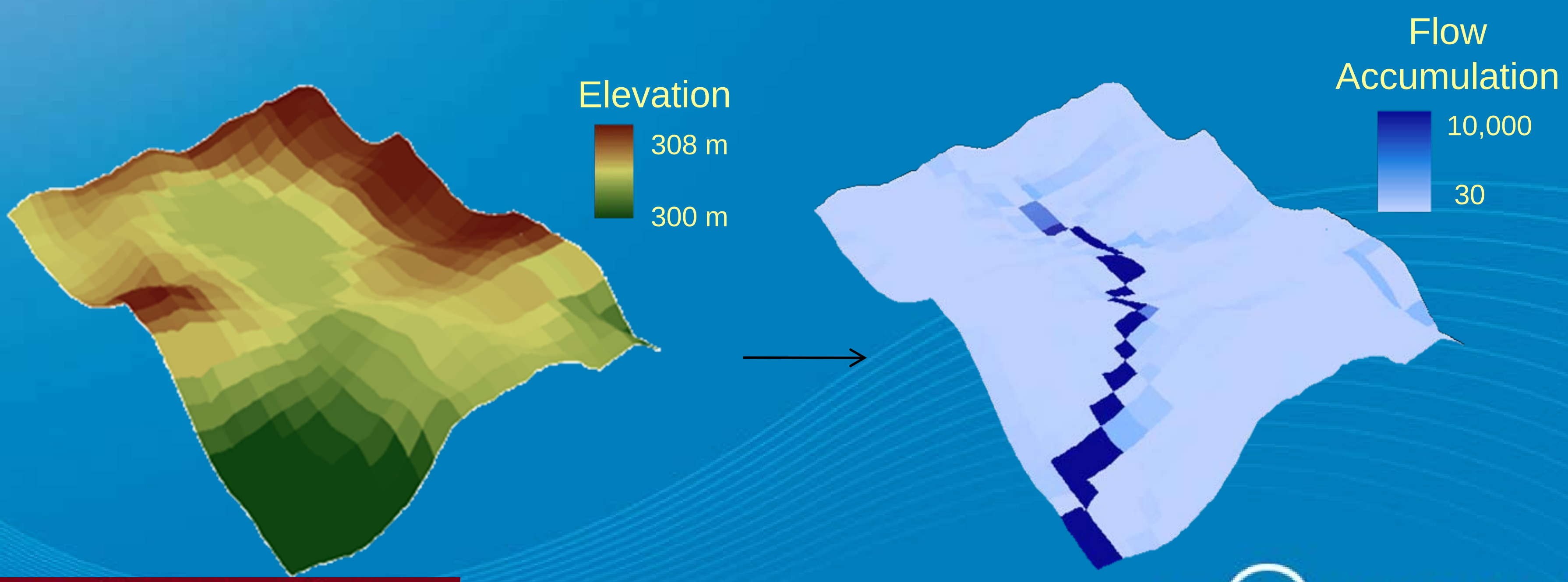
- Primary attribute that quantifies the maximum rate of change in value from each cell to its neighbors
- Describes overland and subsurface flow velocity and runoff rate





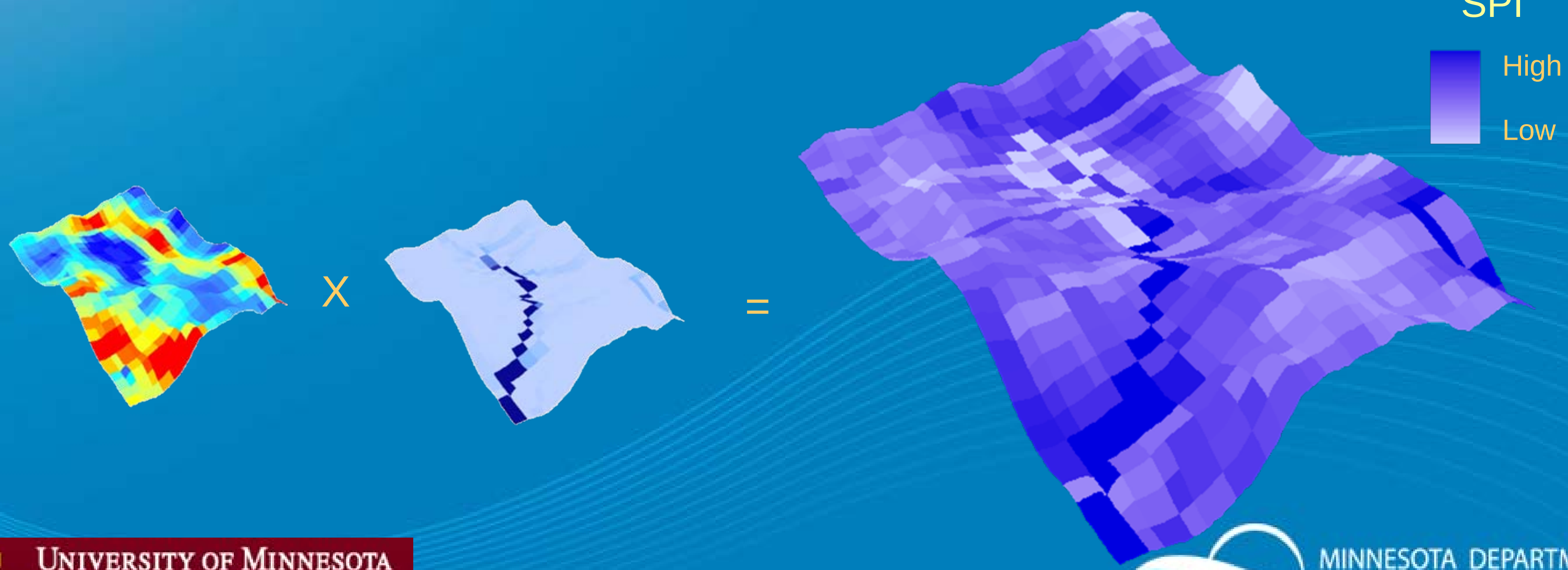
Terrain Attributes: Flow Accumulation

- Primary attribute representing the drainage area of any given cell
- Indicates overland flow paths
- Also known as catchment area, upslope contributing area



Terrain Attributes: Stream Power Index

- Secondary attribute: product of Slope and Flow Accumulation
- Quantifies the erosive power of overland flow
- Isolates areas with large catchments and steep slopes




Stream Power Index
0
40
80
160 Meters

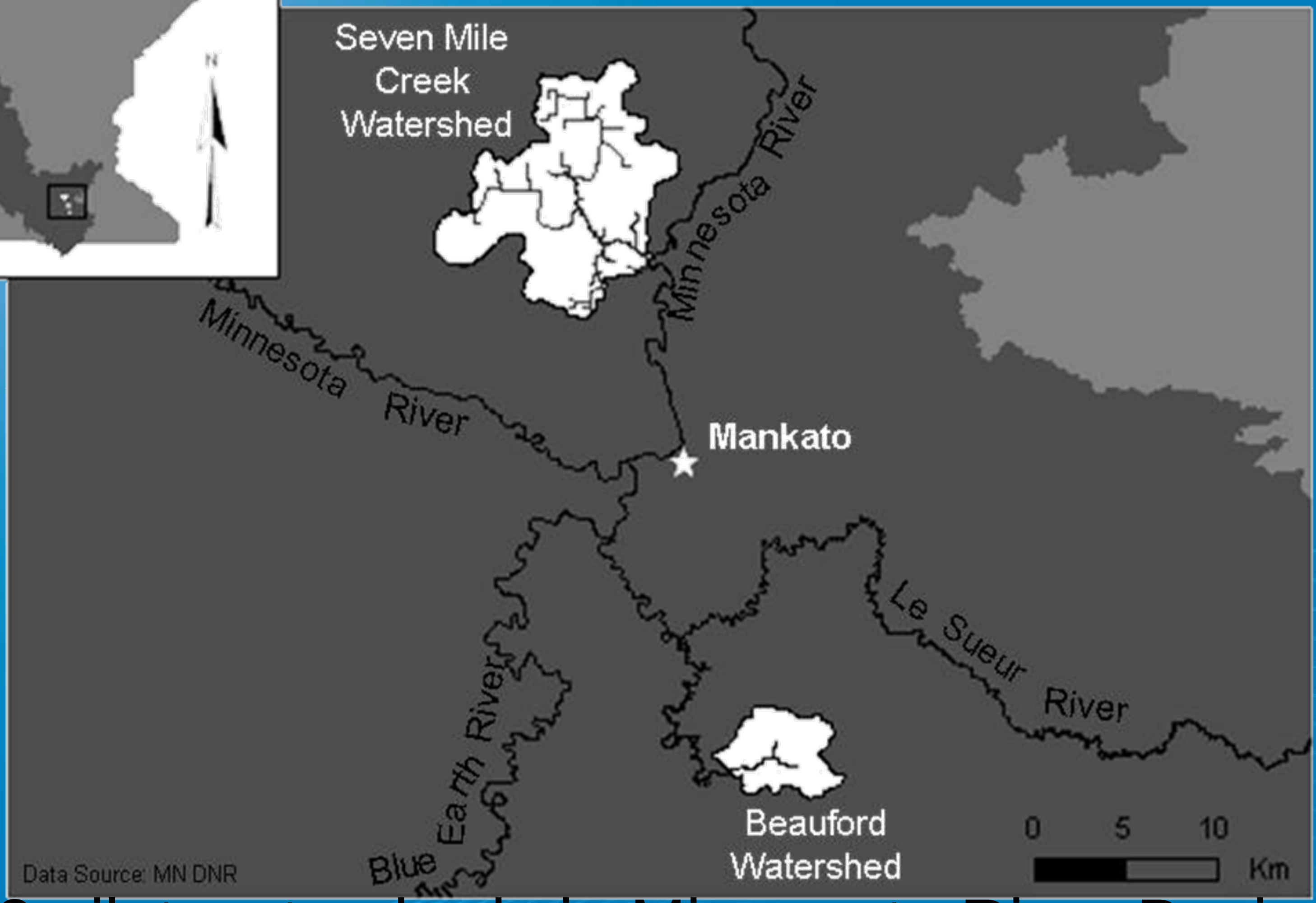
Clean Water Legacy Pilot Study

- Objective is to develop a tool that uses terrain attributes to identify critical source areas vulnerable surface water runoff
  - Study conducted at multiple scales (3,000 ac to 800,000 ac) using different DEM sources.
    - 30m DEM: Le Sueur Watershed
    - 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

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

Study Area



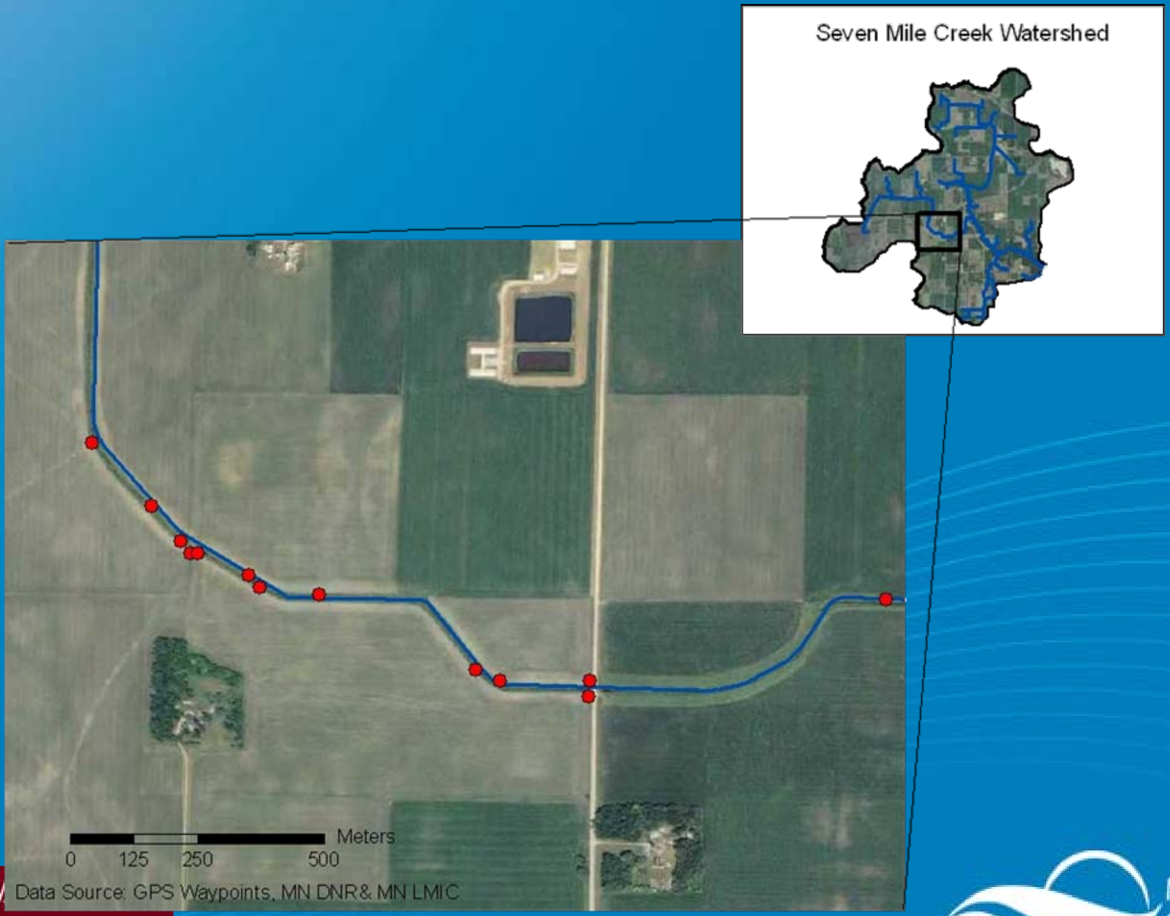
- 2 pilot watersheds in Minnesota River Basin

Field Surveys

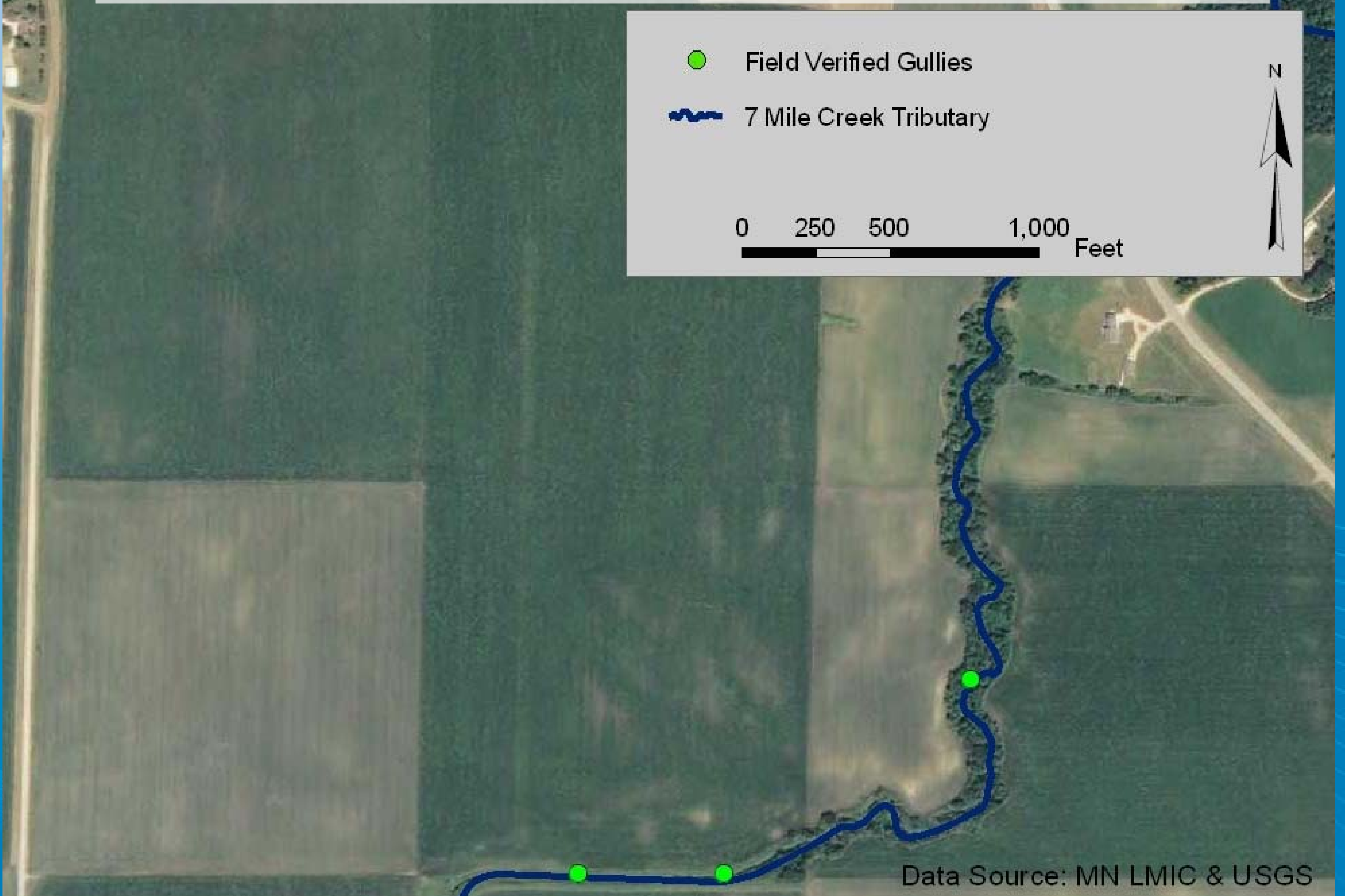
- Handheld Pocket PC with WAAS GPS
- Field Mapping Software
- Tape Measure
- Digital Camera
- Compass
- Log book

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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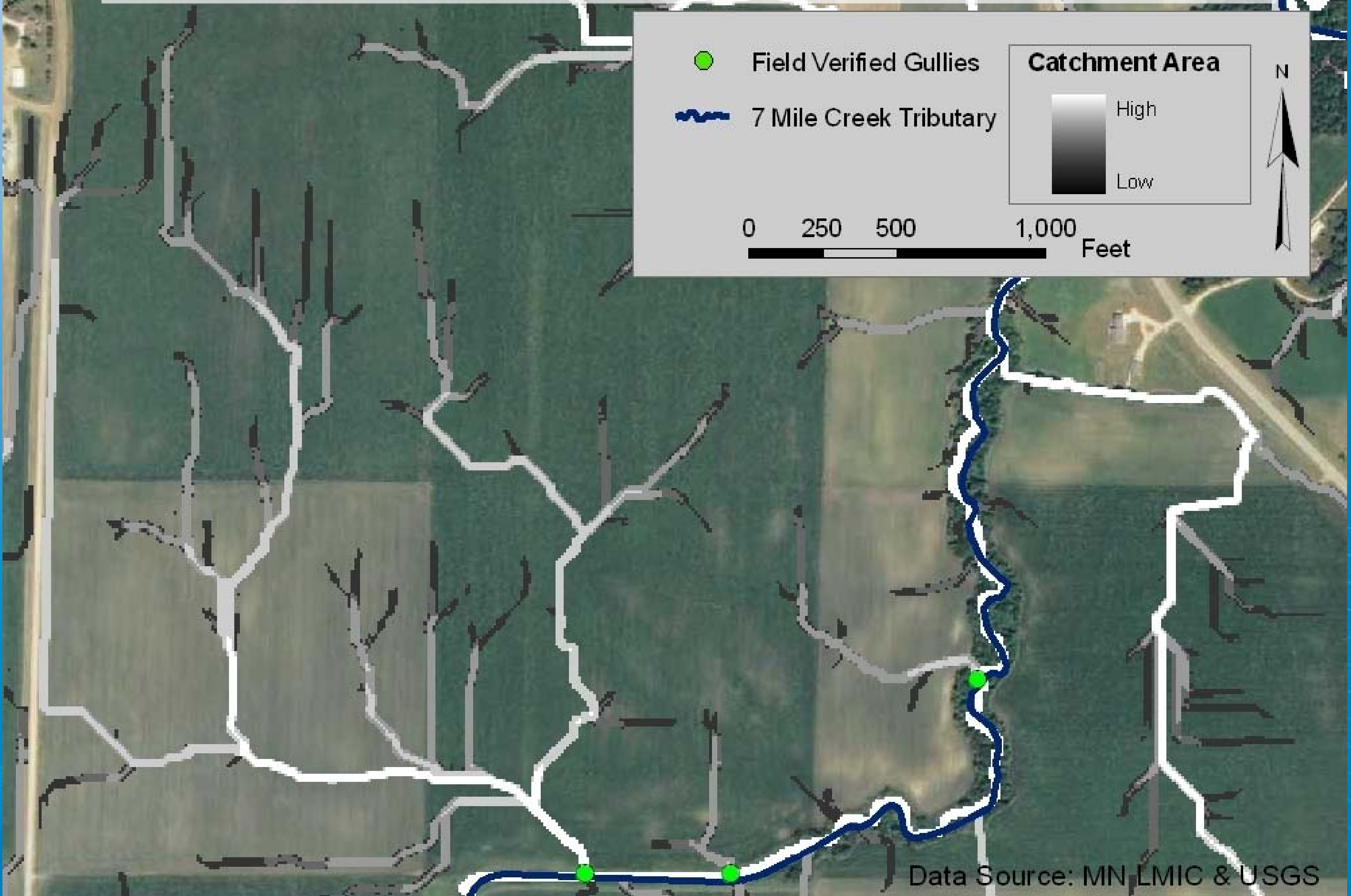

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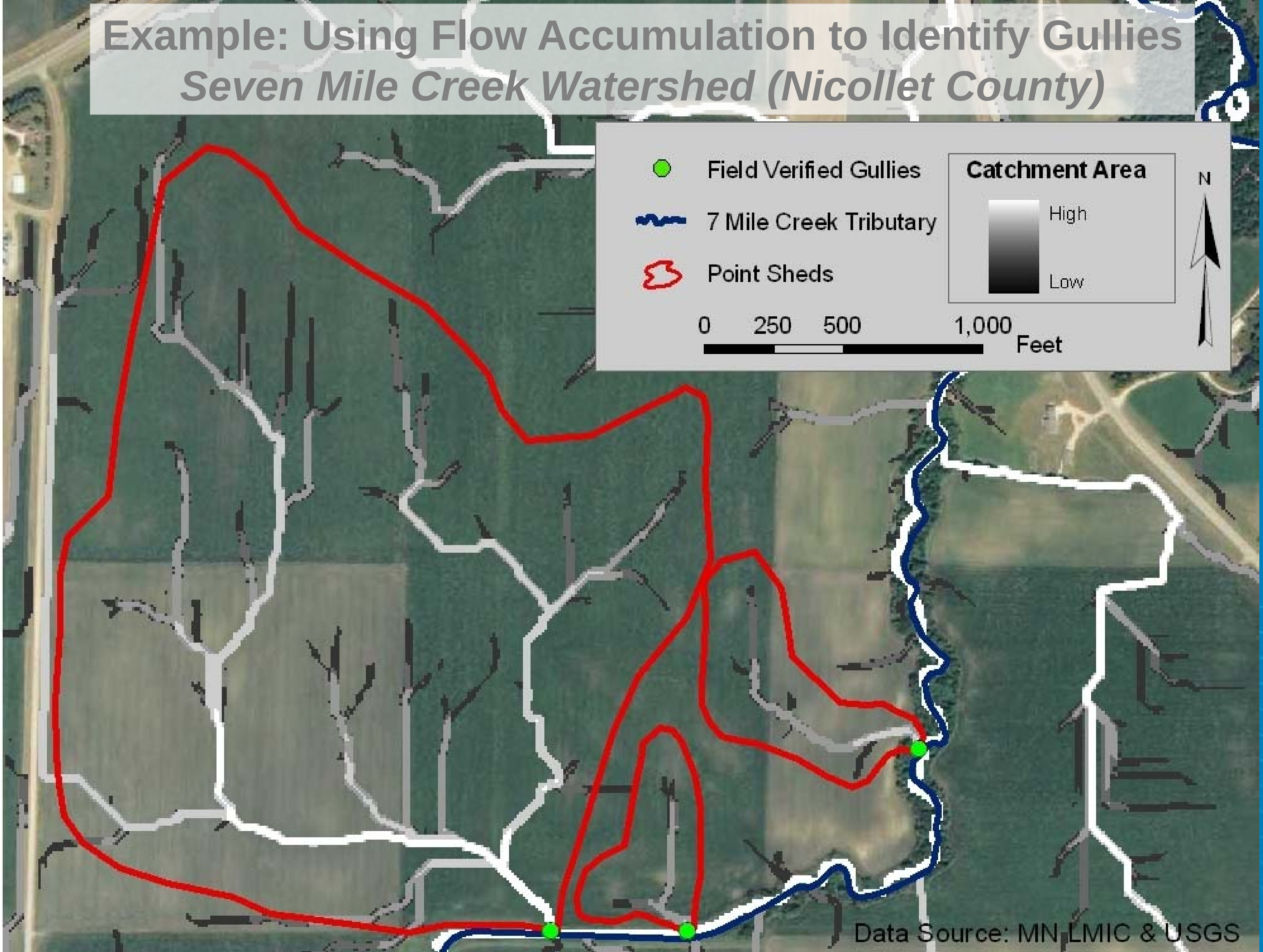
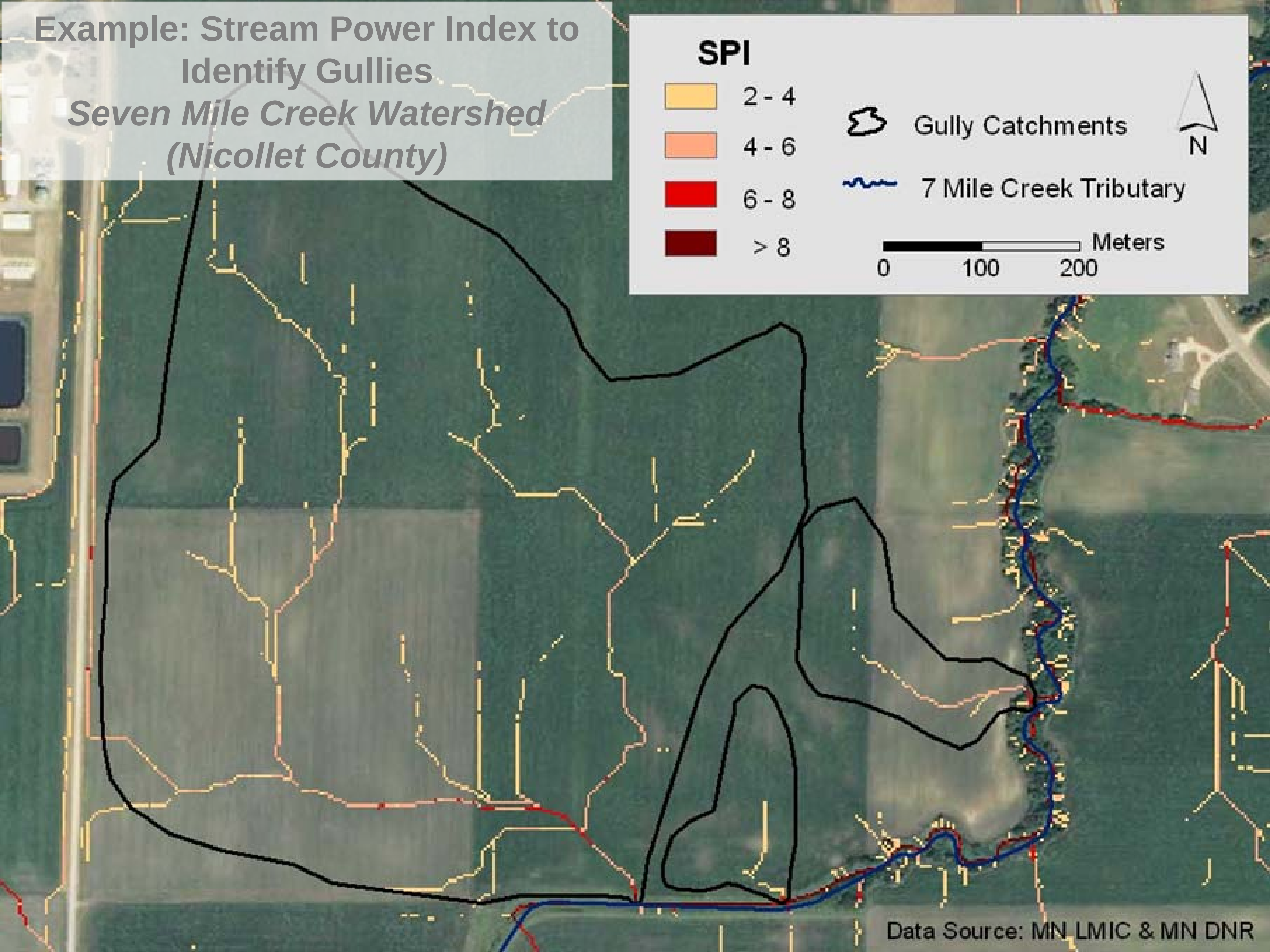


Example: Stream Power Index to Identify Gullies

Seven Mile Creek Watershed (Nicollet County)



Courtesy of the Brown, Nicollet, Cottonwood Water Quality Board

Example: Using Flow Accumulation to Identify Critical Source Areas

Beauford Watershed (Blue Earth County)

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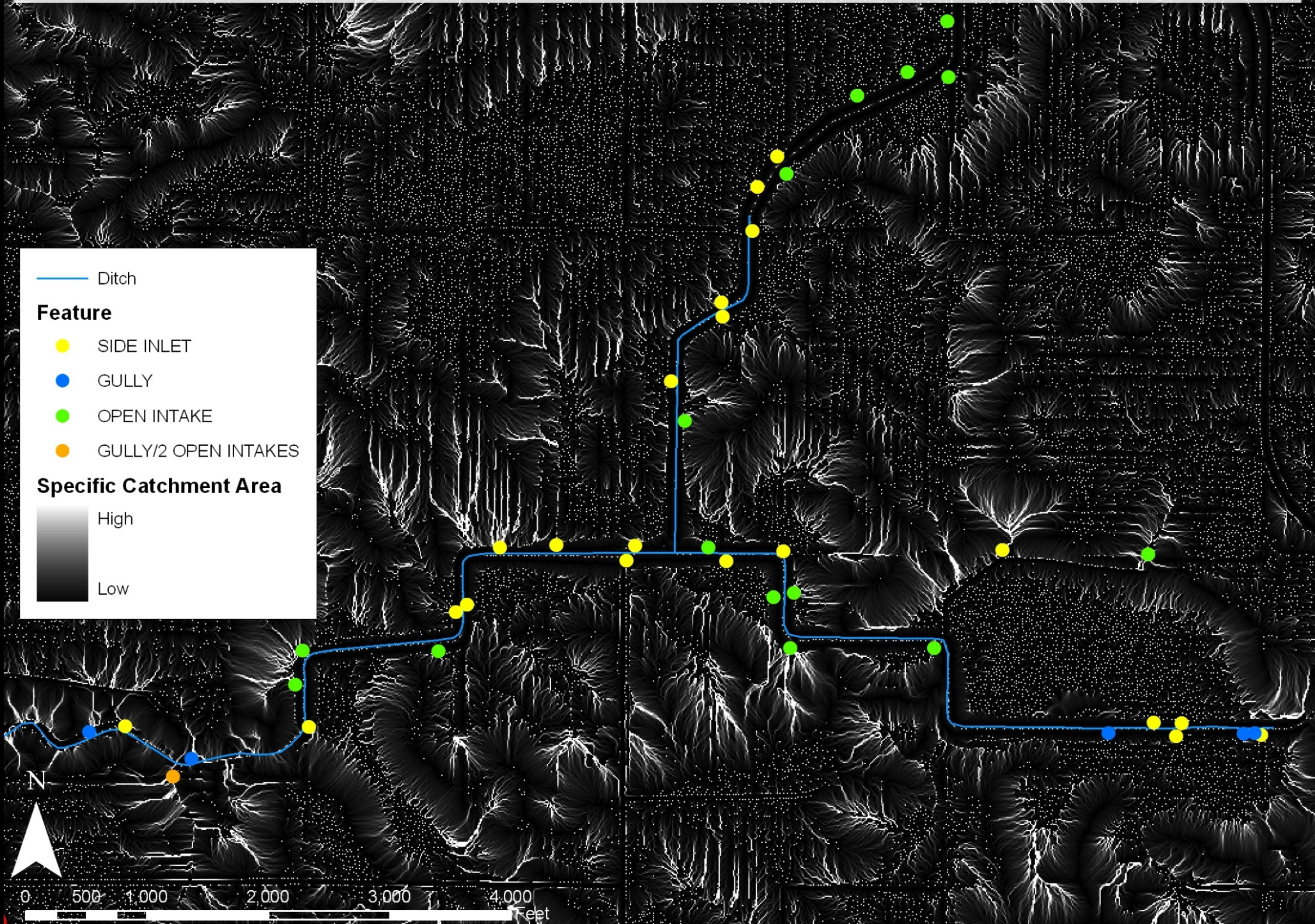
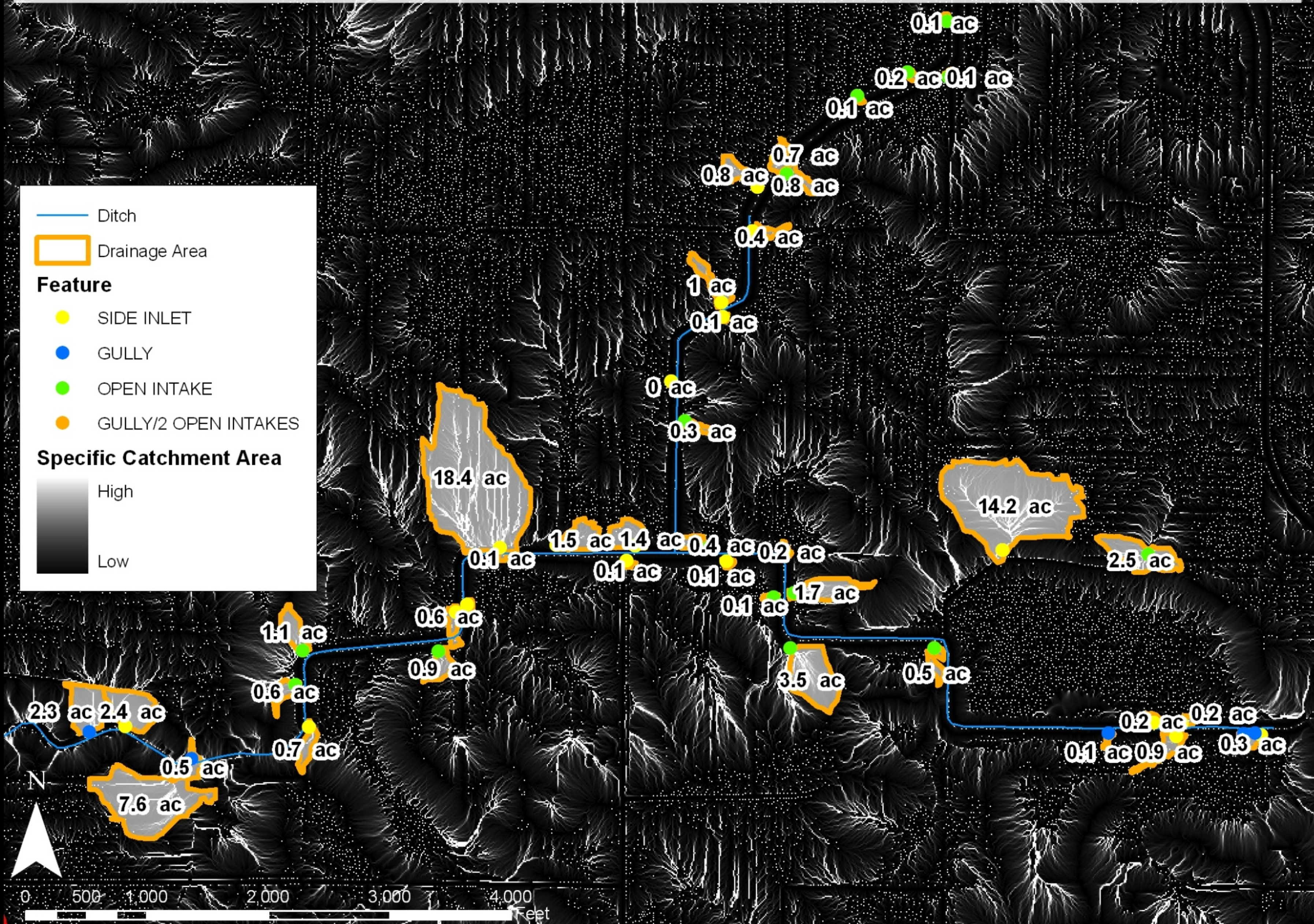
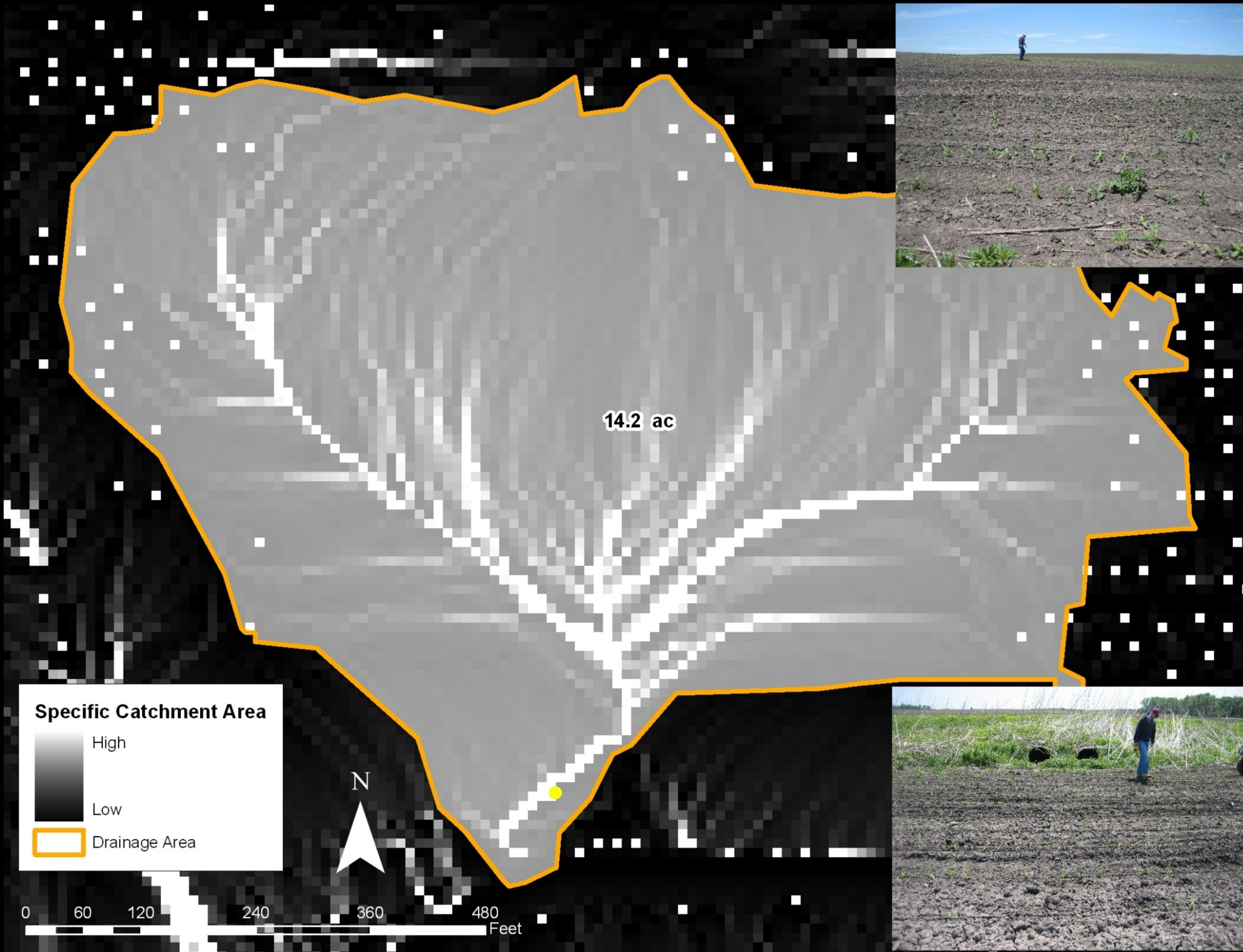
Beauford Watershed (Blue Earth County)

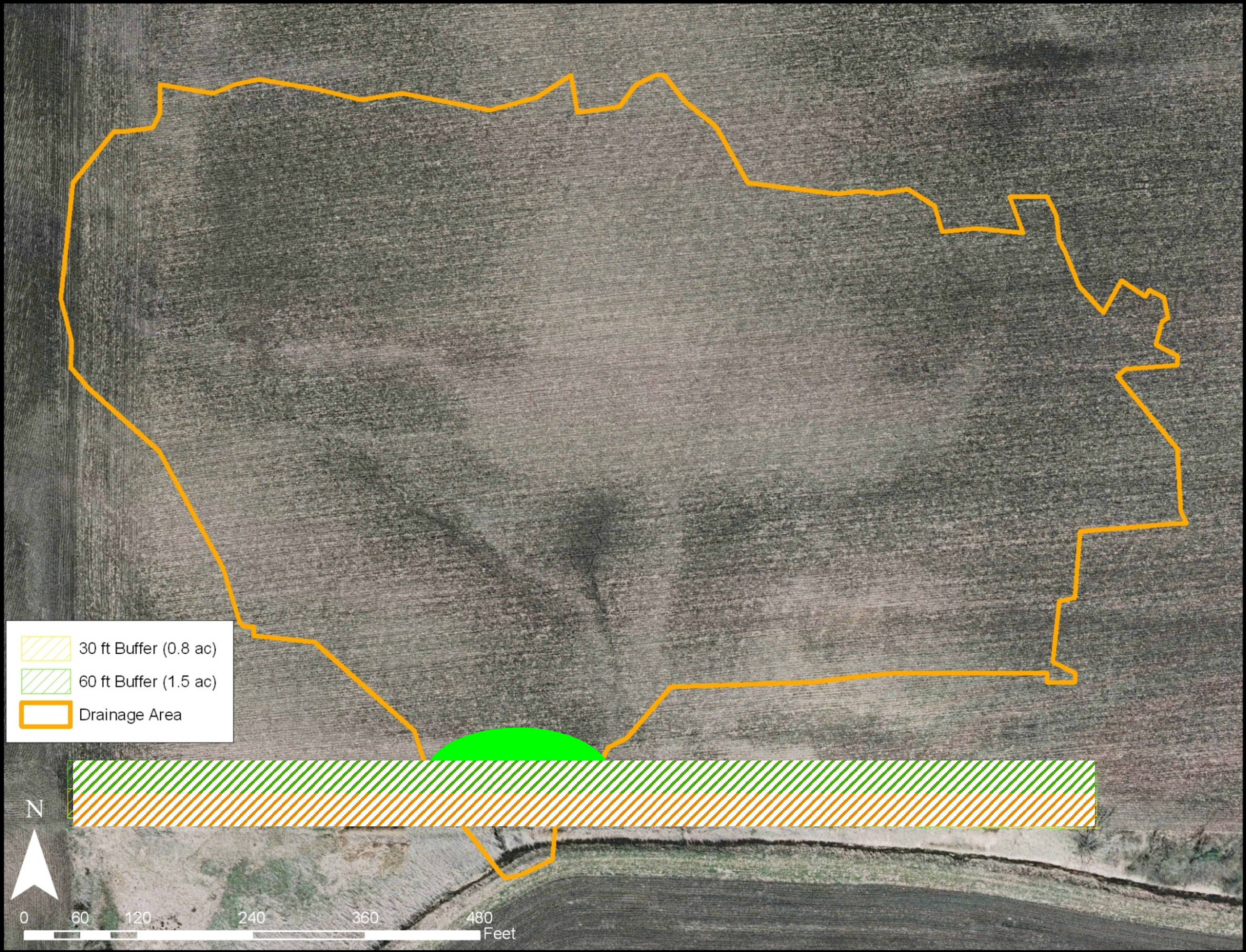


Example: Using Flow Accumulation to Identify Critical Source Areas

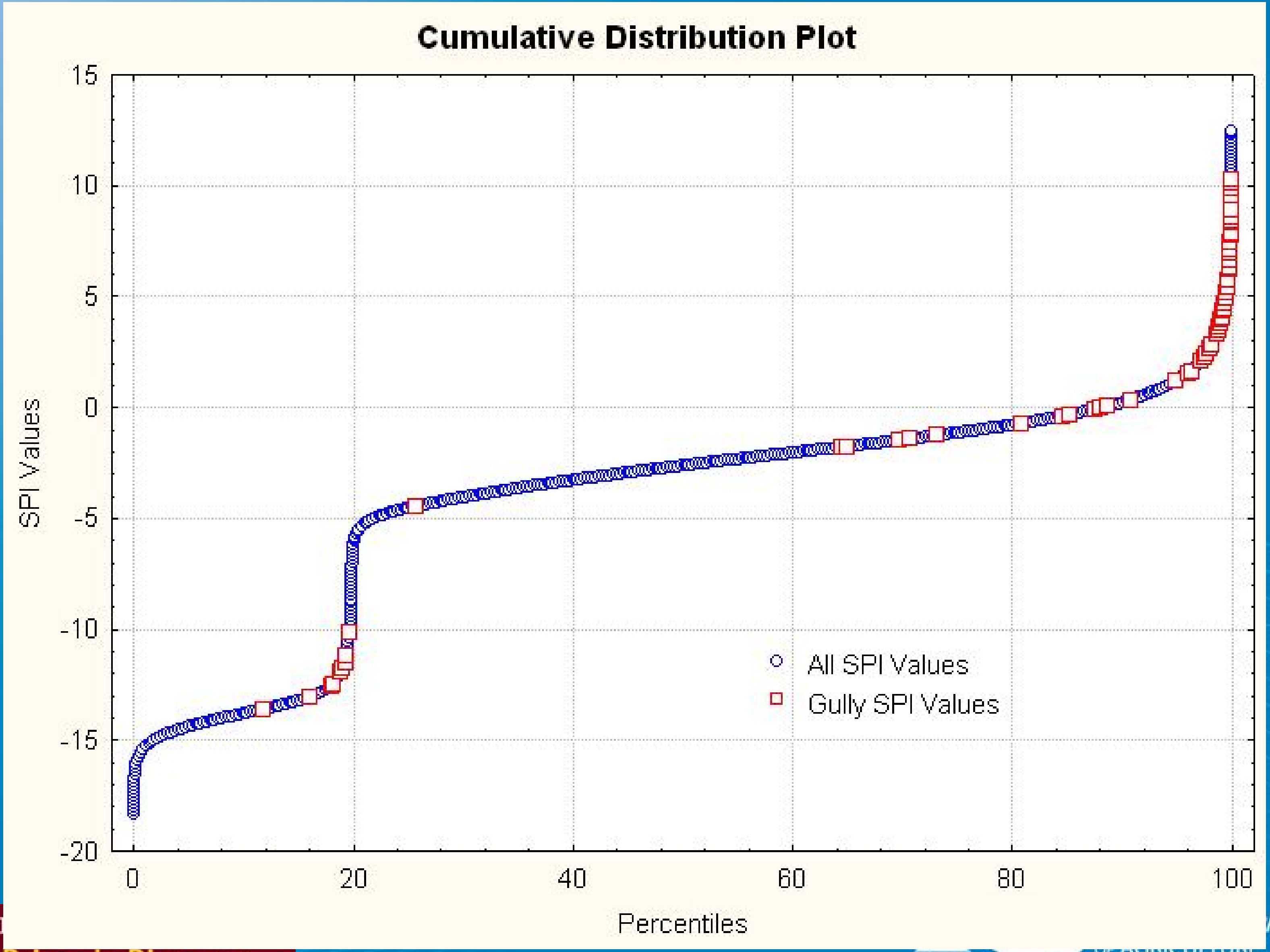
Beauford Watershed (Blue Earth County)




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

Results

- Confirmed that ordinal size of a feature is related to SPI
- Although not a quantitative assessment of delivery potential, values suggest that there is a relationship to the terrain attribute value and the magnitude of the erosion feature.
- Further study including water quality data collection recommended to quantify 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

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
- Estimate 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

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
- These methods are easy to employ and can serve as a valuable use of newly acquired LiDAR data

Next Steps

- CWL project final report:
  - Includes a powerpoint tutorial for processing data and conducting a terrain analysis in ArcGIS.
  - http://www.mda.state.mn.us/protecting/waterprotection/newimpairedwaters.aspx
- Training workshops.
- Pilot the approach with LGUs in 2-3 watersheds.

One-Day Workshop: Digital Terrain Analysis for TMDL Implementation in Minnesota

Learn a process for identifying critical source areas of the agricultural landscape to improve water quality

Register early, as seating is limited. See back ➔

- **Winona State University - Wednesday, April 7, 2010**
- **Minnesota State University (Mankato) - Tuesday, May 11, 2010**
- **St. Cloud State University - Thursday, May 13, 2010**

This one-day workshop is for GIS-trained natural resource analysts involved in locally led Total Maximum Daily Load (TMDL) water quality restoration and/or clean water protection efforts (see prerequisites on back). Participants will learn a scientific process that identifies the best places to implement conservation practices that reduce sediment and sediment-related pollutants. The workshop will transfer this process from the University of Minnesota lab to the GIS desktops of locally led clean water restoration/protection efforts throughout the state. The process was developed and tested by the University with 2007-2009 Clean Water Legacy funding from the Minnesota Department of Agriculture. ***The premise: If clean water goals are to be met, funding for clean water implementation must be targeted to high-contributing areas of the landscape.***

Workshop Objectives

* Participants will receive instruction and hands-on practice in calculating the **Stream Power Index**, the **Compound Topographic Index** and other terrain attributes.
* Participants will practice applying these calculations to high-resolution **LiDAR data** so as to identify field gullies, side inlets and other fine-scale erosion and runoff features.
* Participants will practice interpreting terrain attribute values and images.
* Participants will leave the workshop with the knowledge and skills needed to apply digital terrain analysis to their own clean water efforts (assuming they have access to ArcGIS Desktop).

These workshops are part of the Minnesota Department of Agriculture (MDA) Clean Water Fund project ***Piloting Local Use of Targeting Tools for Clean Water Implementation.*** *FOR MORE INFORMATION, CONTACT:*

MINNESOTA DEPARTMENT OF AGRICULTURE

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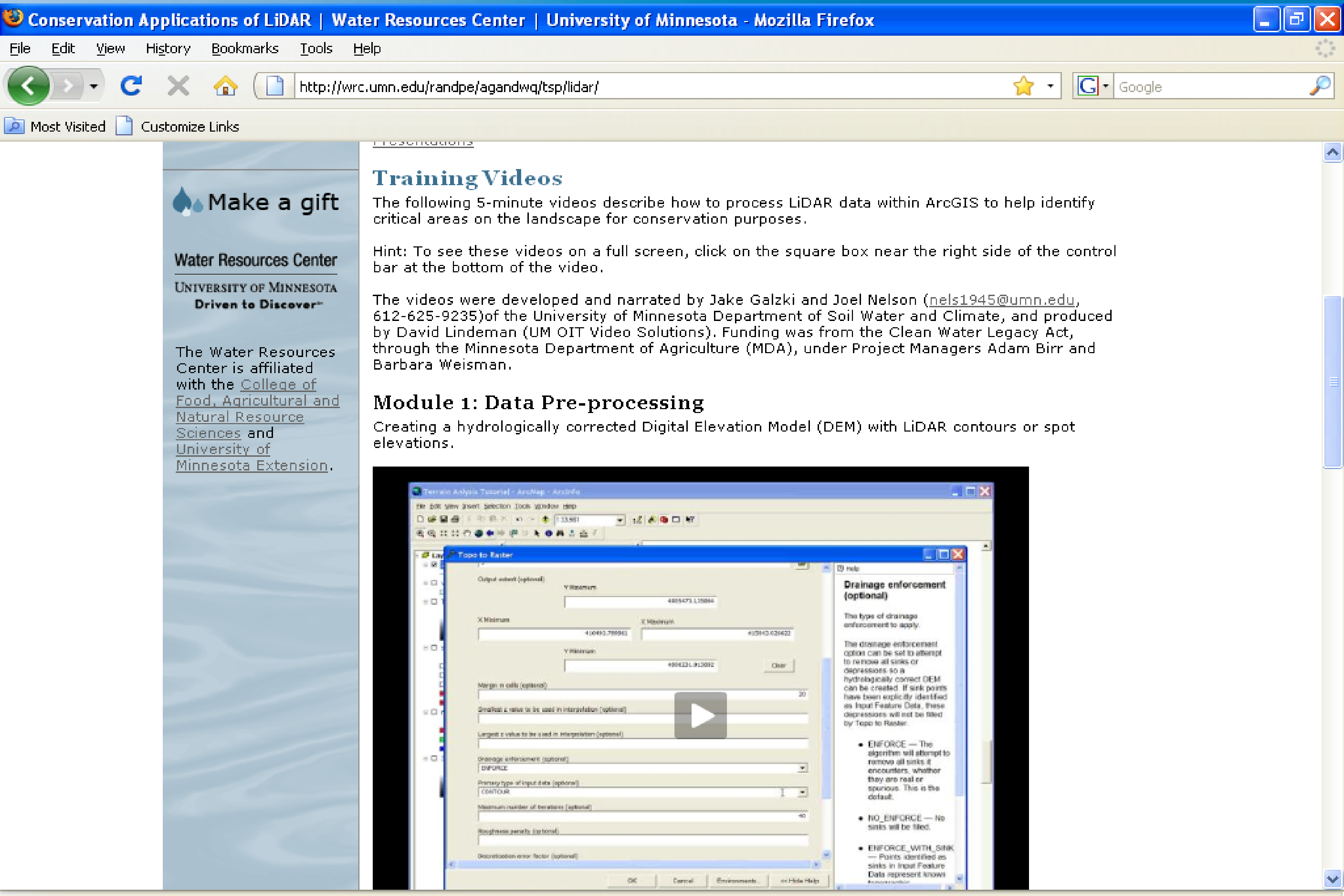
Adam Birr, Minnesota Department of Agriculture, 507-206-2881, Adam.Birr@state.mn.us

http://wrc.umn.edu/randpe/agandwq/tsp/lidar/



Questions?

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