

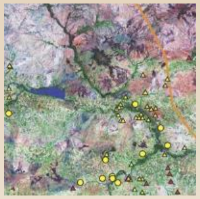

An Approach for Sub-Field Level Identification of Phosphorus Critical Source Areas in a Region Dominated by Saturation Excess Runoff

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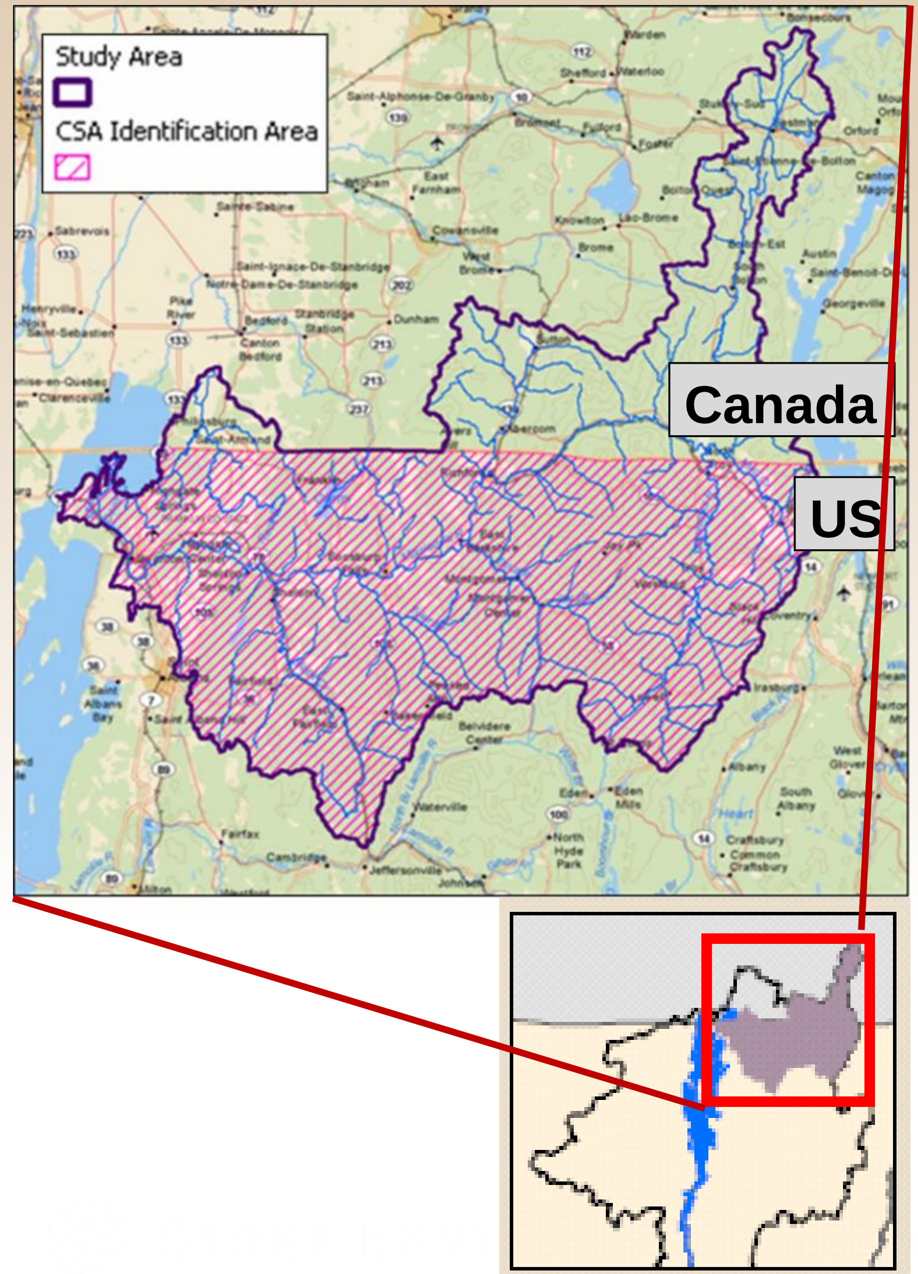
Images from Lake Champlain Basin Program

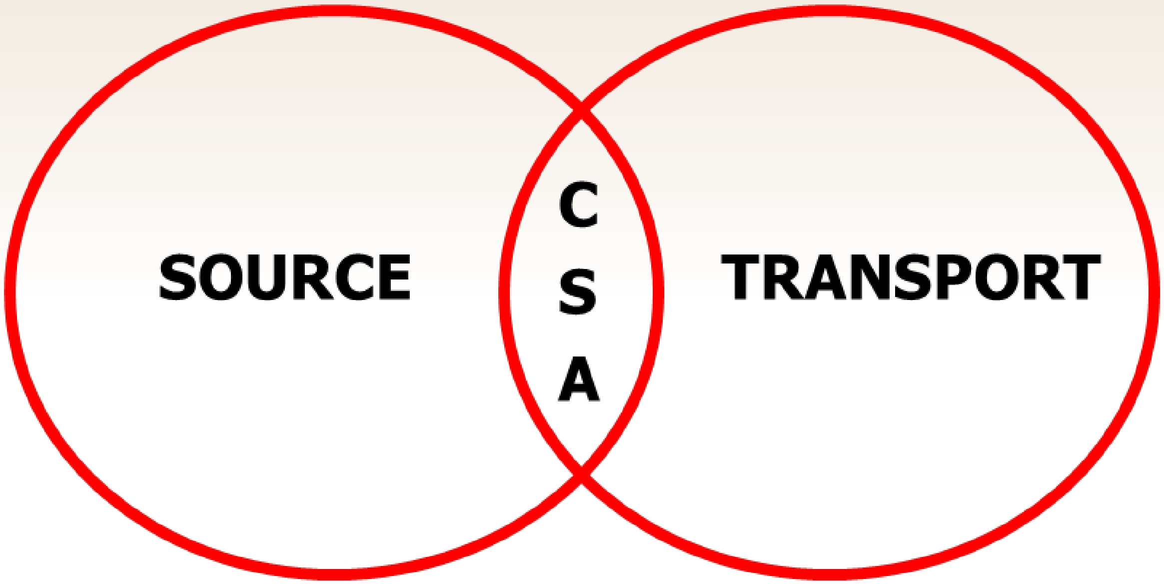
Background and Objectives:
Project Study Area

- Study Area:
  - Missisquoi Bay Basin (MBB)
  - Along international boarder of US (Vermont) and Canada (Quebec).
  - 2,539 km^2
  - 67% forest
  - 17% agriculture
  - 12% undeveloped
  - 4% developed
- Critical Source Area (CSA) Identification Area:
  - All areas in VT that contribute to the Missisquoi Bay Basin (US focused)
  - Greater resources focused on input data development and model output resolution and analysis



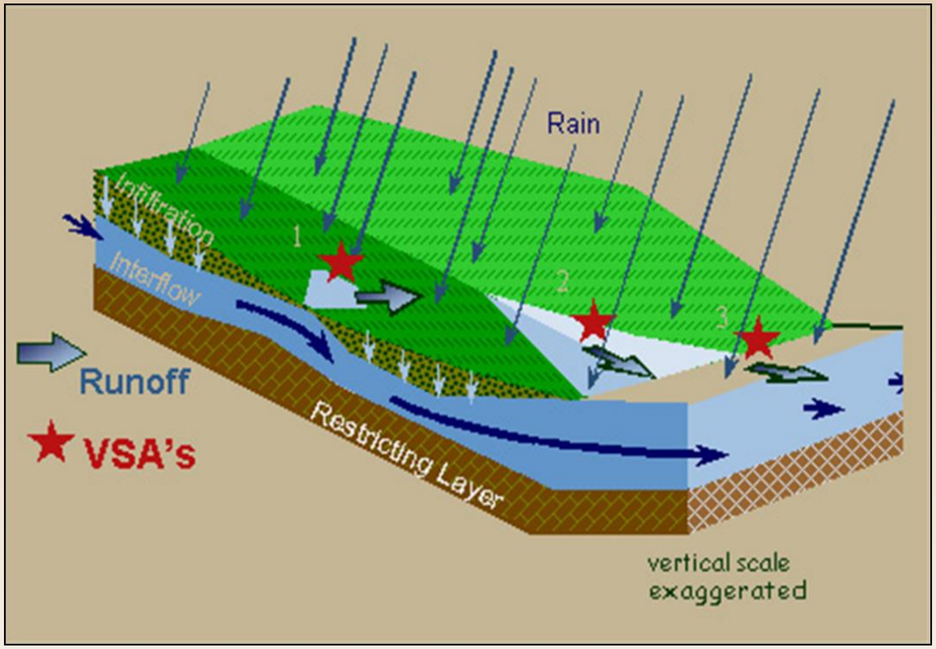
Background and Objectives: Critical Source Areas

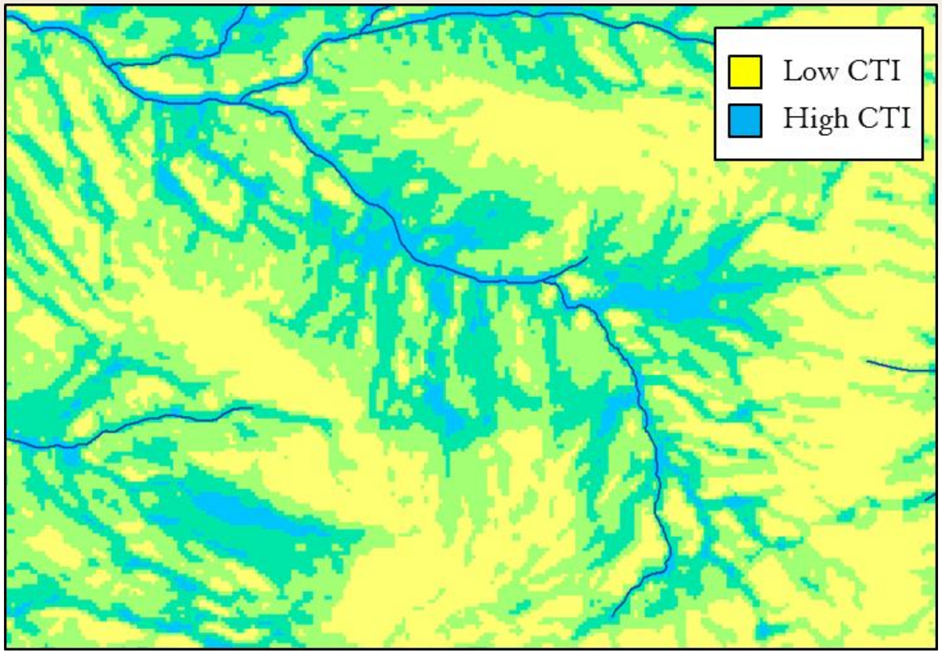
- Critical Source Area (CSA) = Phosphorus (P) source + transport
- P source = P stocks (e.g., soils) + current management
- Transport = runoff, erosion, proximity to water
- In the Northeast United States, runoff response is dominated by saturation excess from variable source areas. (Dunne and Black, 1970).



Background and Objectives: Variable Source Areas, Compound Topographic Index

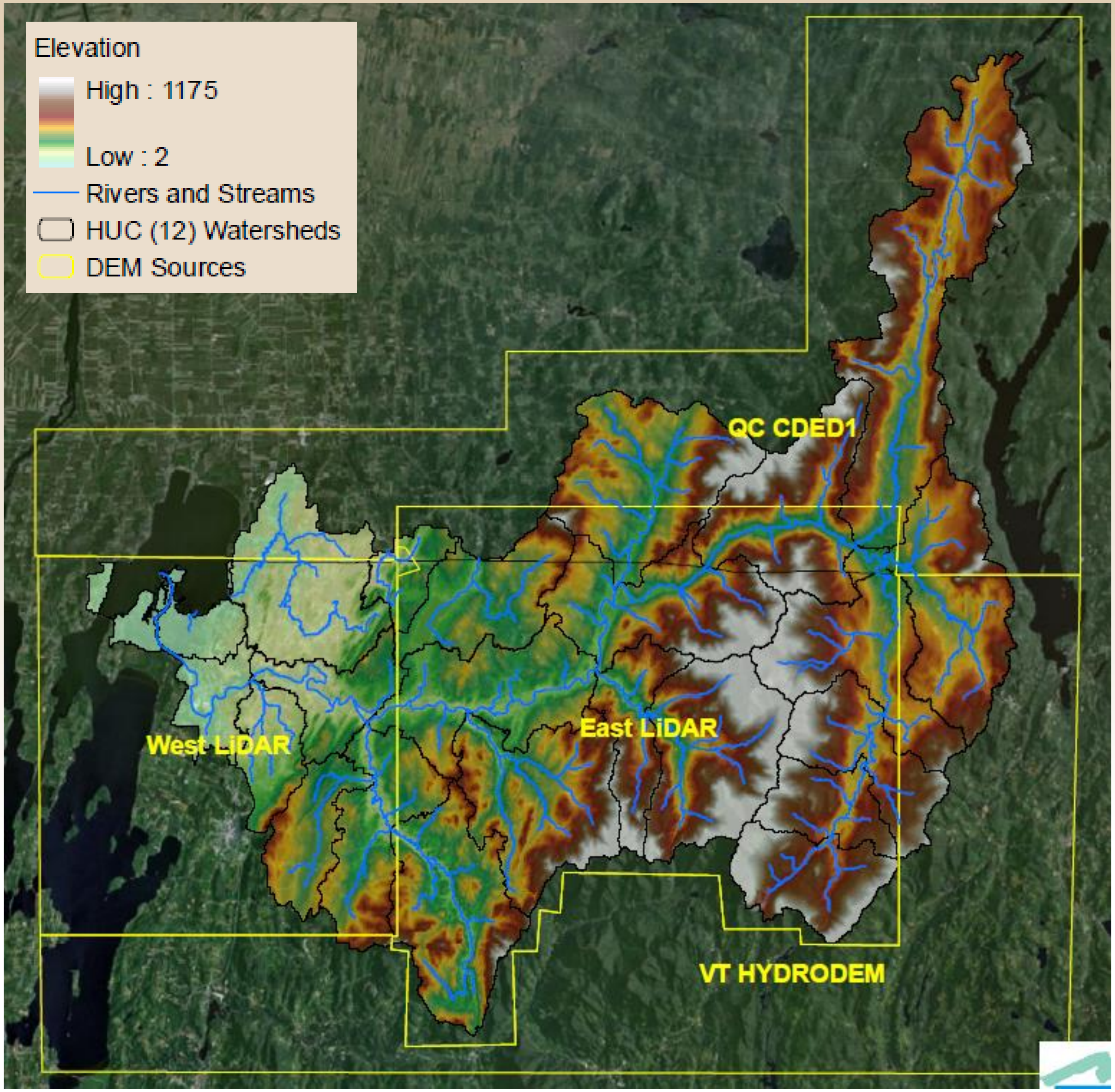
- The compound topographic index has long been used to model variable source area hydrology. (Beven and Kirkby, 1979)
- CTI = ln(a/ tan(b))
  - a = upslope contributing area
  - tan(b) = slope
- High CTI indicates high potential for saturation excess runoff,
  - As “a” increases, CTI increases
  - As tan(b) increases, CTI decreases
- Low slope, high upslope area = high saturation potential





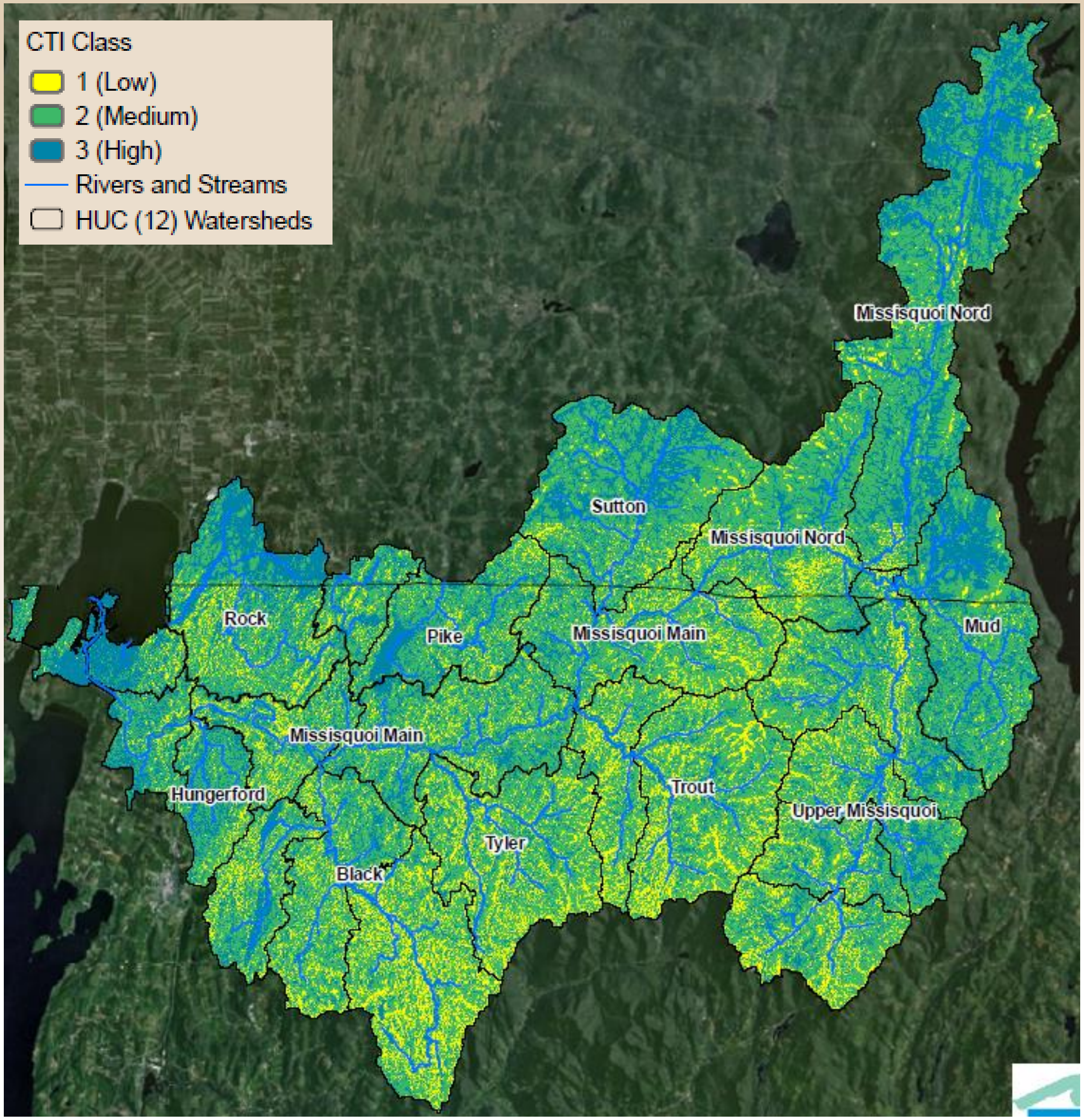
Model Development: Topographic Data

- High-resolution (1.6 m) LiDAR data was available for much of the study area.
- Other topographic data sources with lower resolution (10 m to 20 m) were available for remainder of the study area.
- All sources were merged to create a 10-m Digital Elevation Model (DEM) covering the study area.

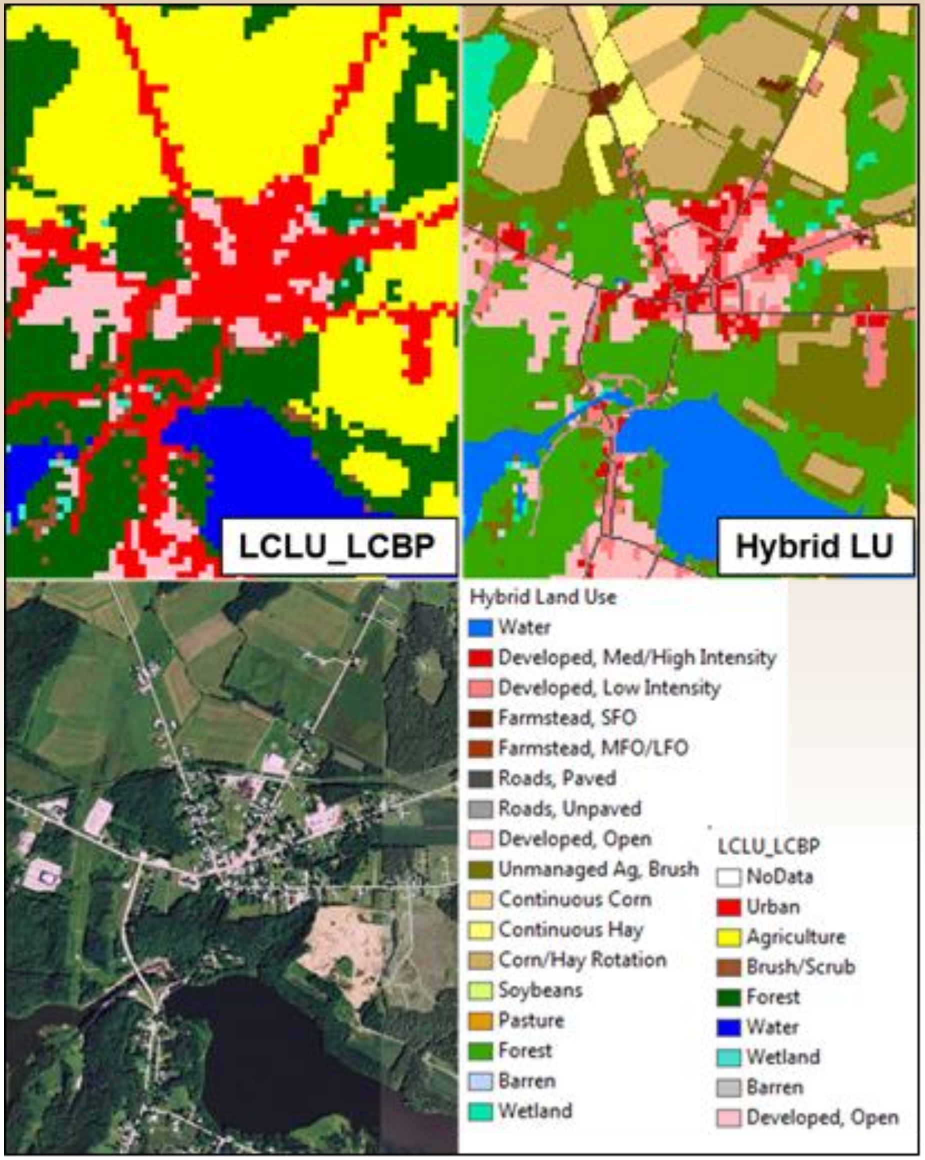


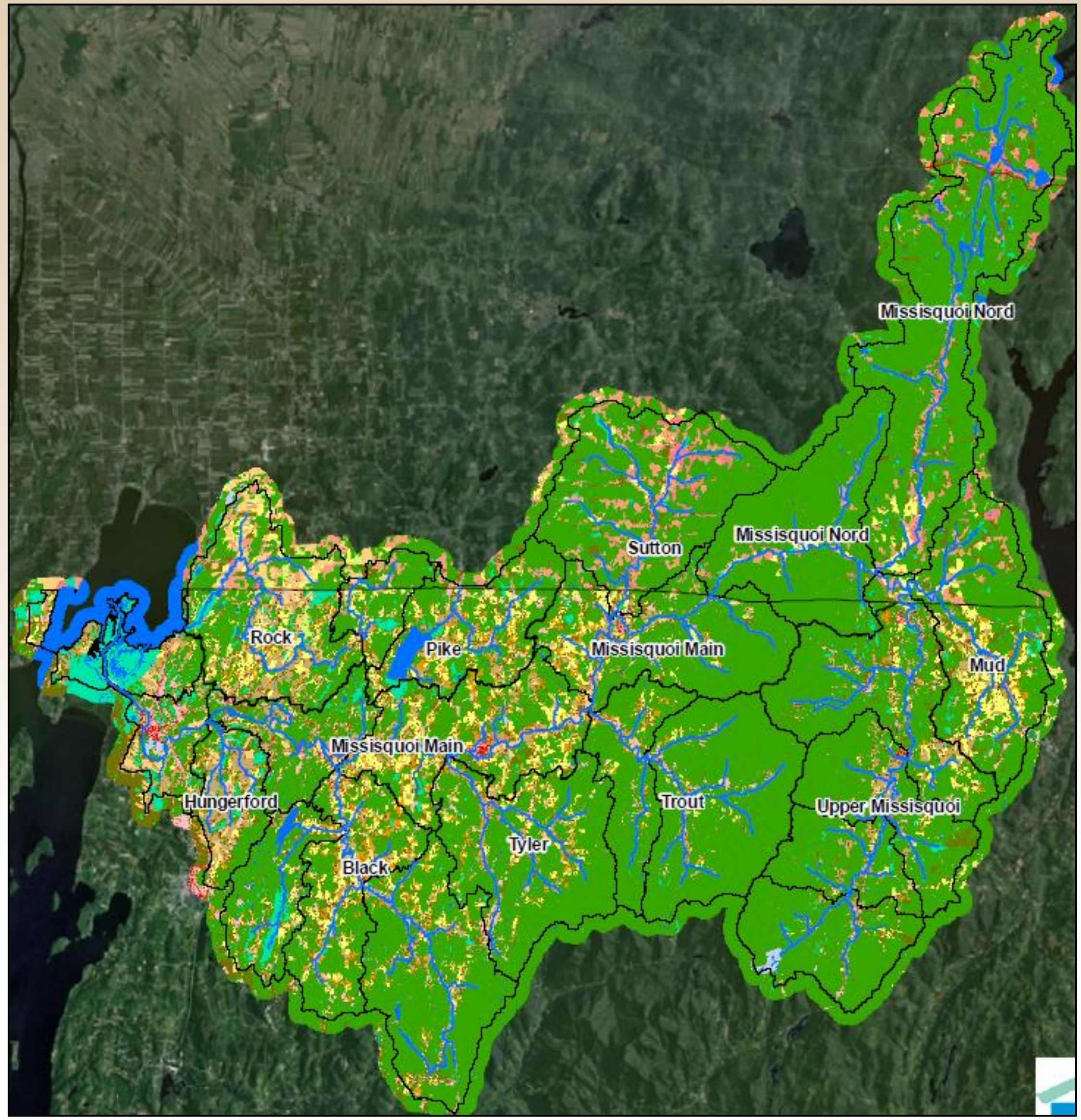
Model Development: CTI Distribution

- A Compound Topographic Index dataset (CTI) was developed for the study area.
- CTI divided into 3 classes
  - Class 1(Lower 20%): lower runoff potential
  - Class 2(Middle 60%): moderate runoff potential
  - Class 3 (Top 20%): higher runoff potential
- Lower CTI values occur in steeper, upslope areas
- Higher CTI values occur in flatter, downslope areas



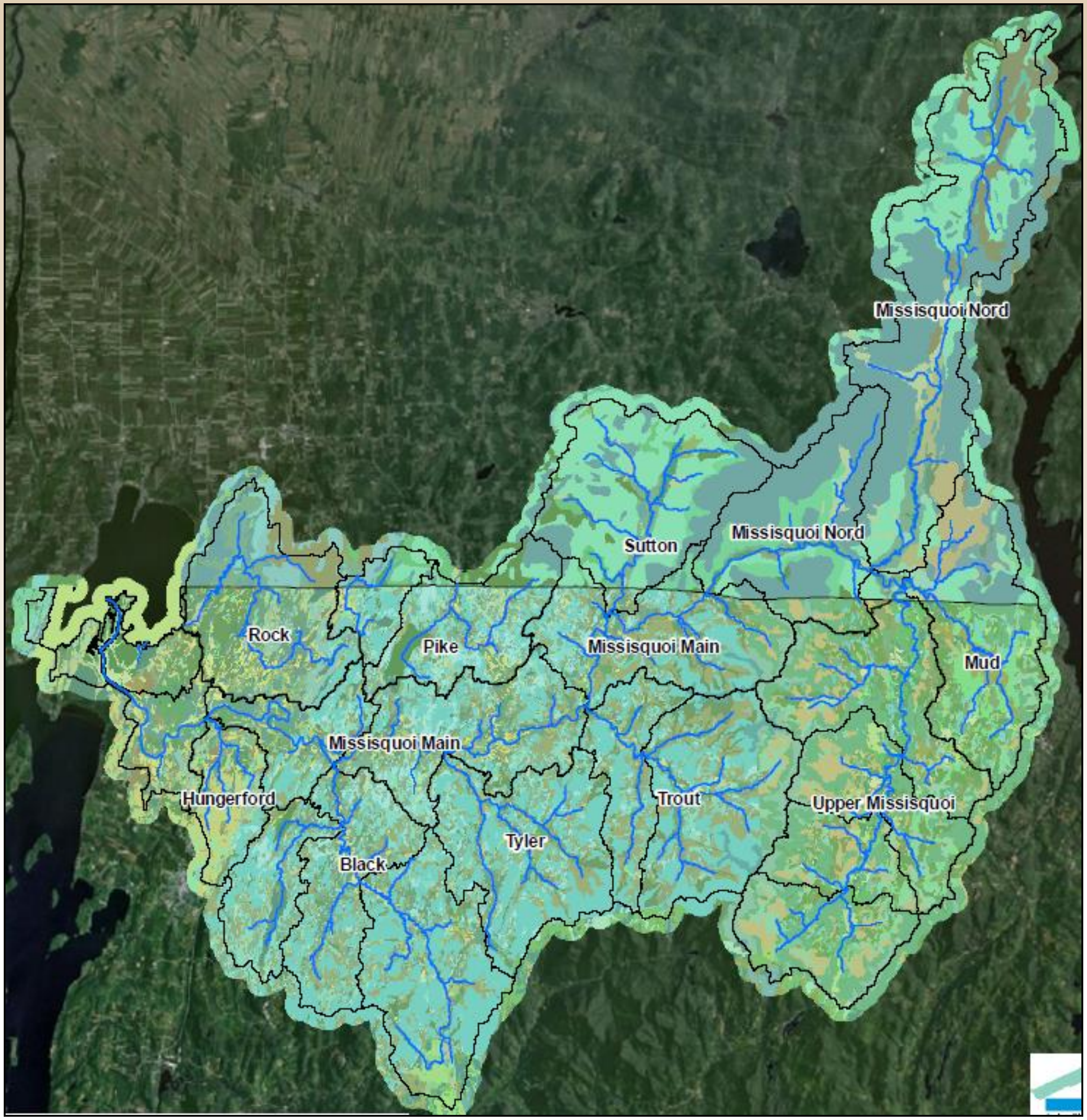
Model Development: Land Use





Model Development: Soil Data

- VT Side:
  - NRCS SSURGO dataset (1:24,000 scale)
  - 303 soil map units aggregated to112 unique soils
- Quebec Side:
  - Based on 1:63,000 scale dataset
  - 26 unique soils

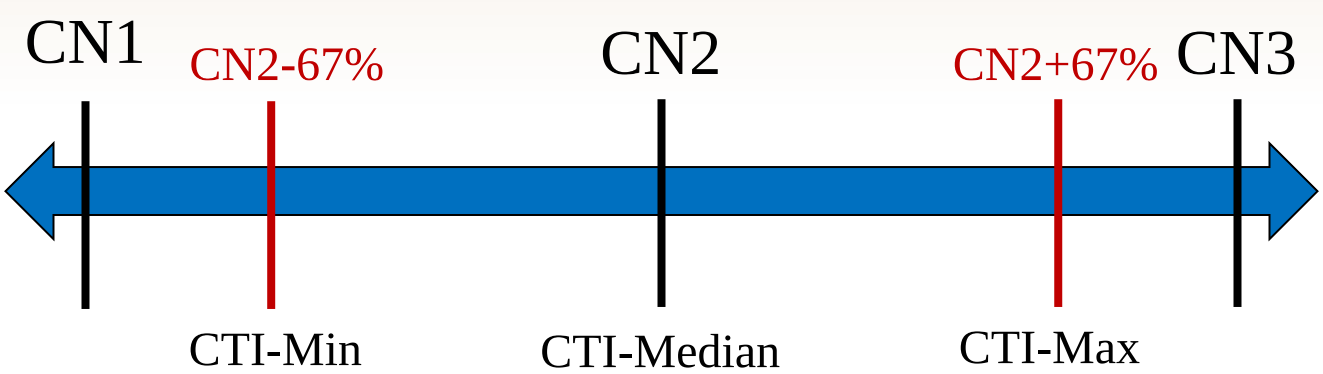


Model Development:
HRU Delineation

- HRUs were delineated based on the following characteristics:
  - Subbasins (223)
  - Land use class
  - Soils class
  - CTI class
  - Field boundary ID (CLU)
- In total, the model consisted of 109,811 HRUs.

Model Development:
CTI Use in Identifying Runoff Potential

- SWAT uses SCS runoff curve numbers in surface runoff calculations.
- The SCS curve number is traditionally a function of land cover, and soil hydrologic group.
- Areas with higher CTI values are prone to greater saturation excess runoff.
- For each land use and hydrologic group, the standard CN2 values were adjusted to reflect the saturation excess runoff potential based on the cumulative distribution percentile of the HRUs local CTI.

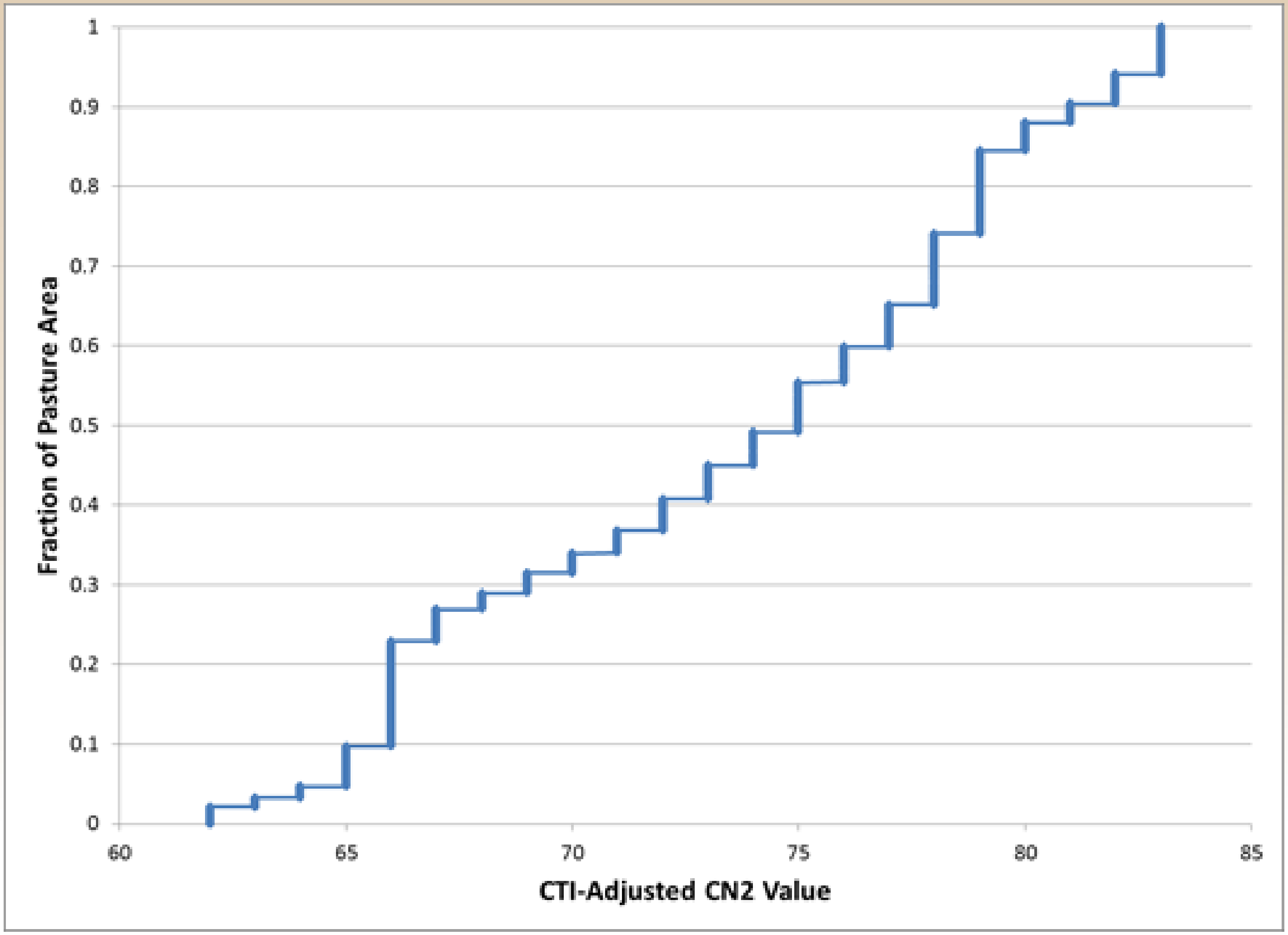


Model Development: CTI-Based Curve Number Definition

- The CTI percentile for an HRU was based on all land uses and soils in the watershed.
- This resulting distribution of CN2 values for a given land use / soil hydrologic group combination varied between:

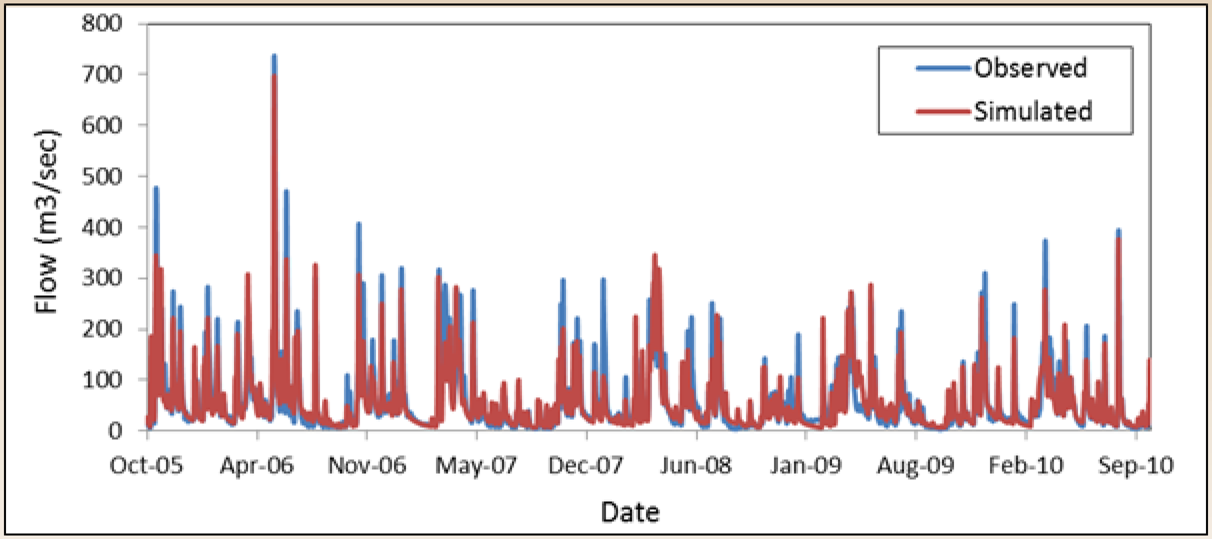
  CN2 – (0.67 * (CN2-CN1))

  CN2 + (0.67 * (CN3-CN2))



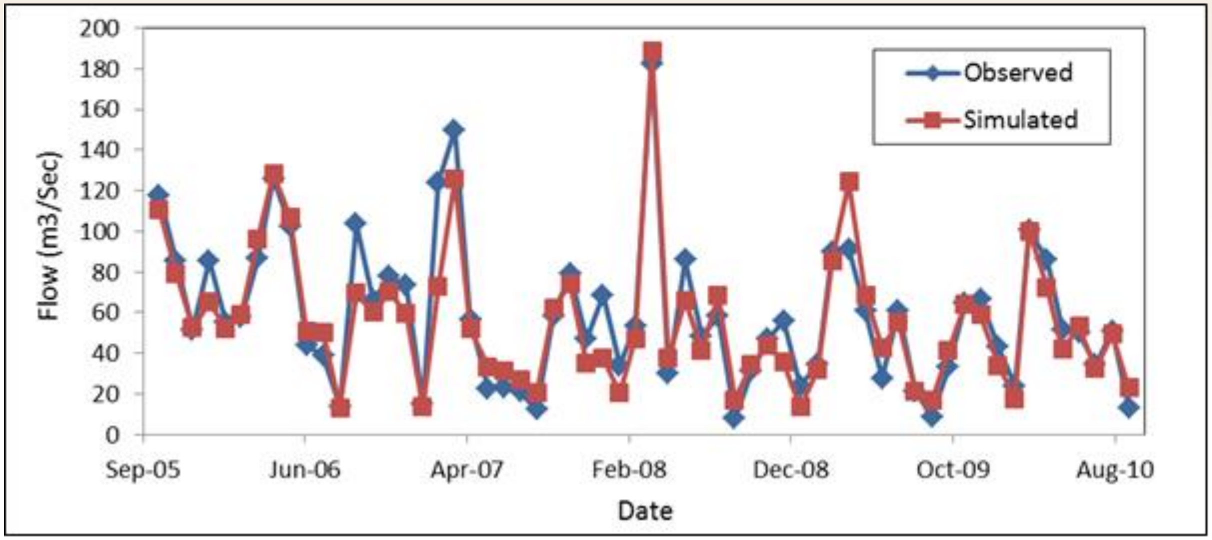
Pasture, Hydro Group C Curve Numbers

Model Calibration:
Hydrology Calibration Results



Missisquoi at Swanton
Daily, Calibration

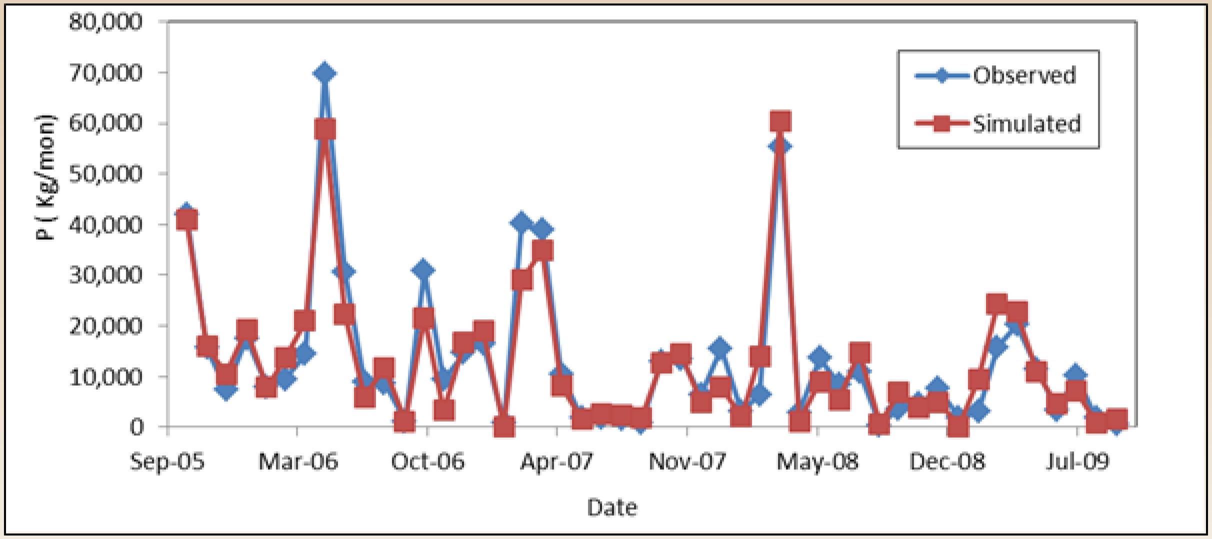
NSE = 0.77
PBIAS = 5.1%



Missisquoi at Swanton
Monthly, Calibration

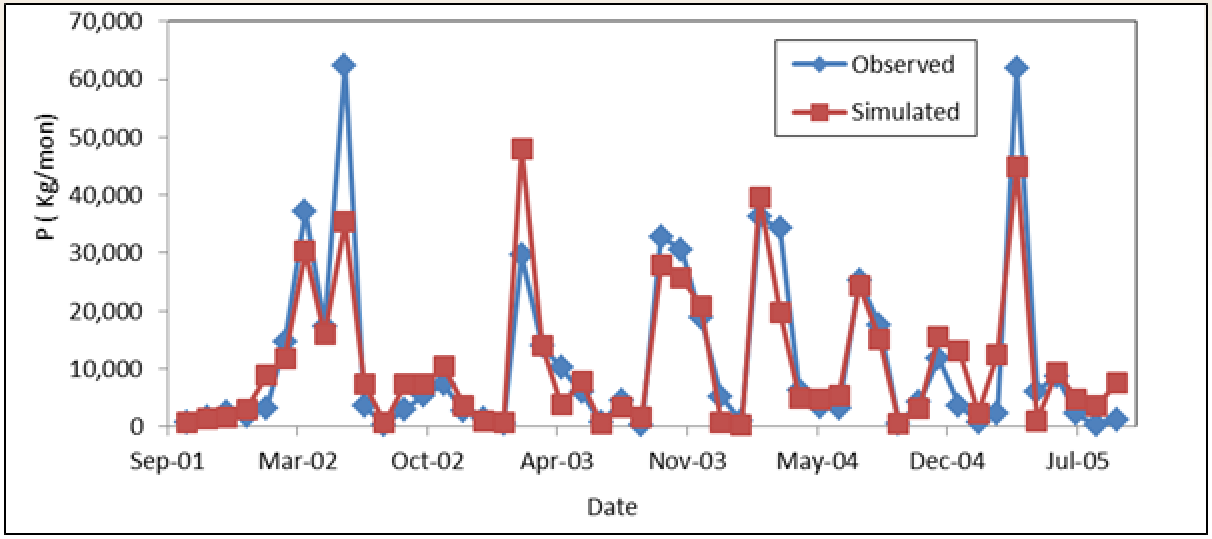
NSE = 0.86

Model Calibration:
Phosphorus Calibration Results



Missisquoi at Swanton
Monthly, Calibration

NSE = 0.91
PBIAS = 3.2%

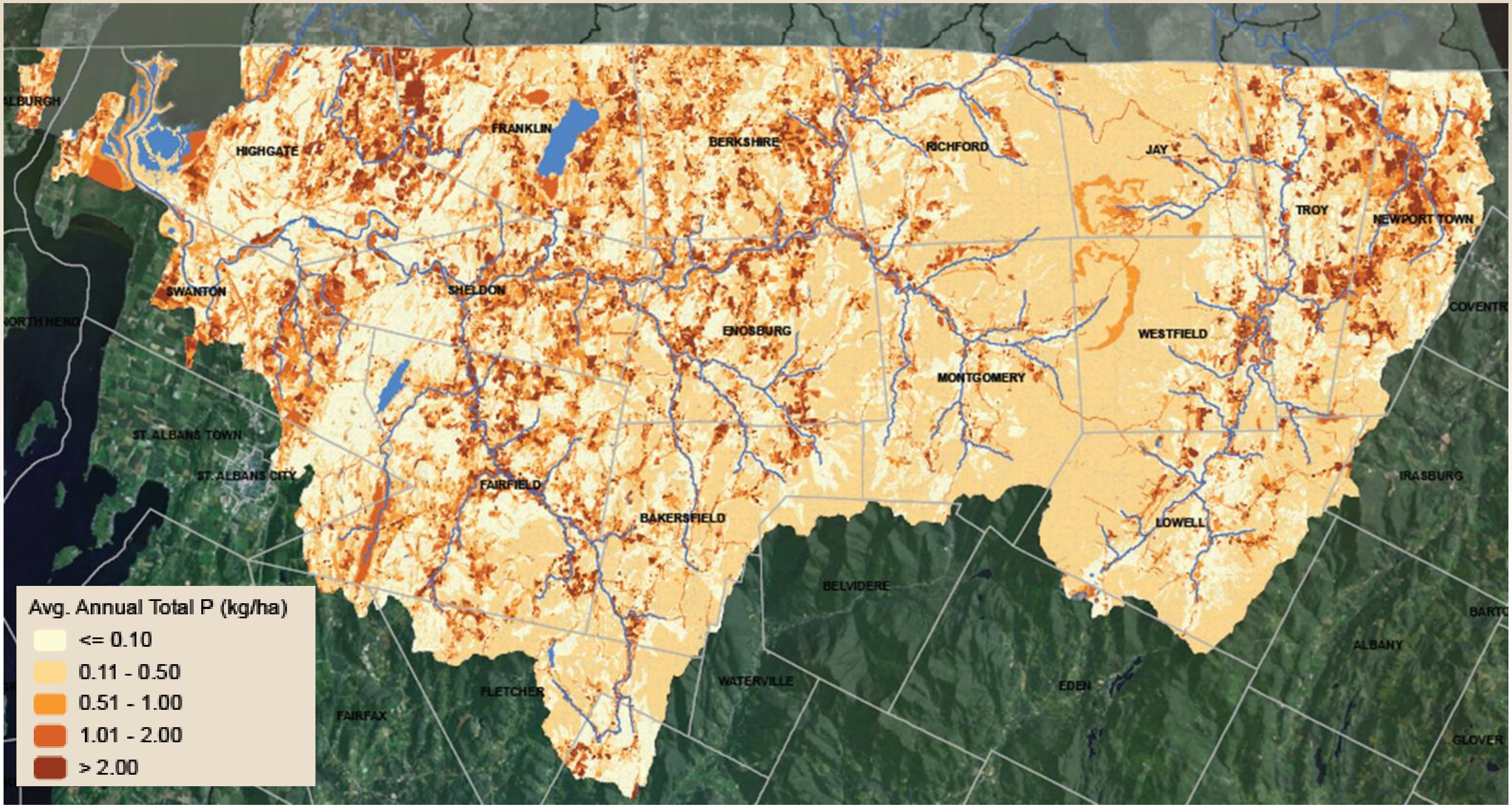


Rock River at St. Armand
Monthly, Calibration

NSE = 0.70
PBIAS = 1.4%

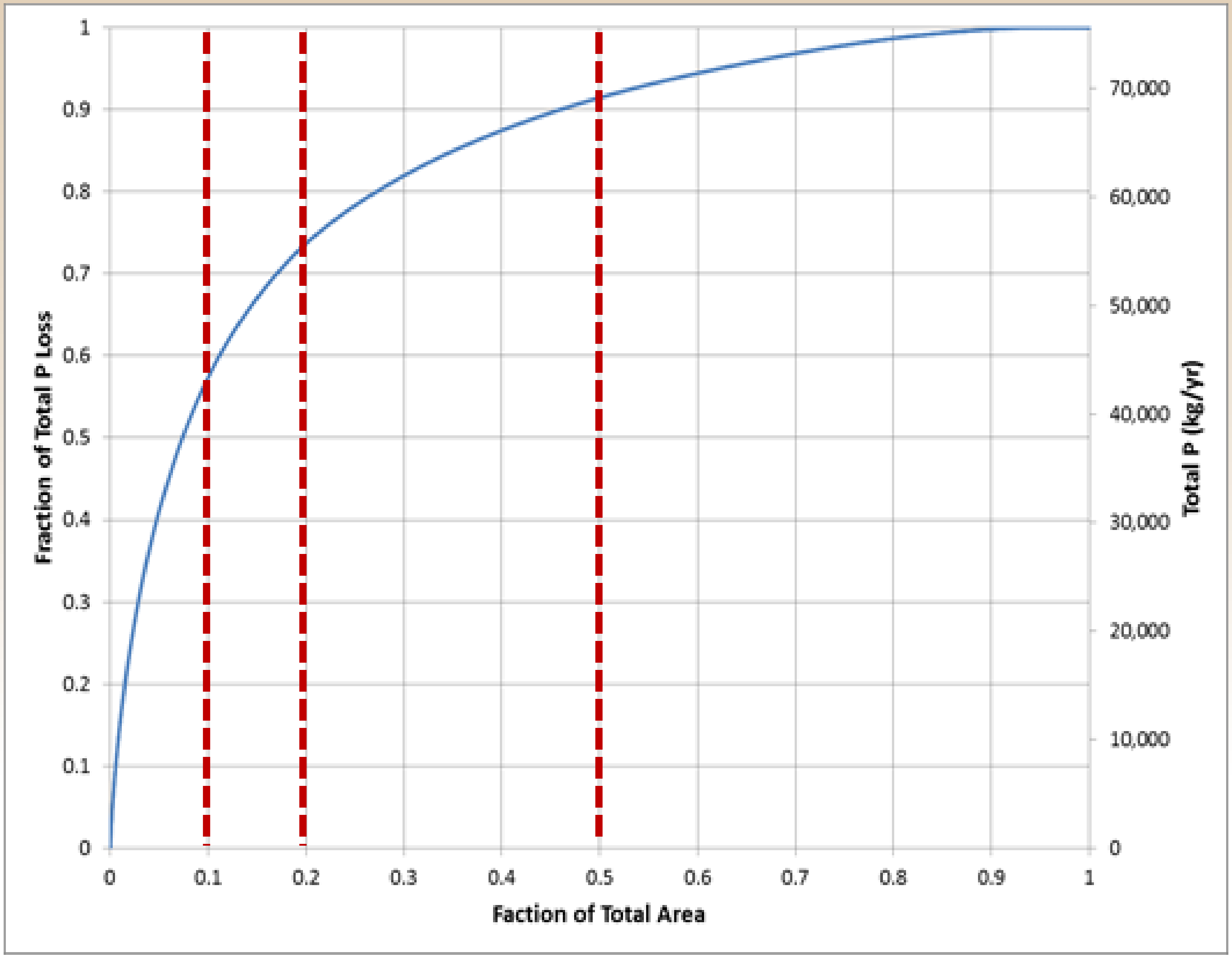
Model Application: HRU Level Results

- Average annual P loading rates were calculated for the 103,666 Vermont sector HRUs.
- Results reflect HRU physical and management characteristics.



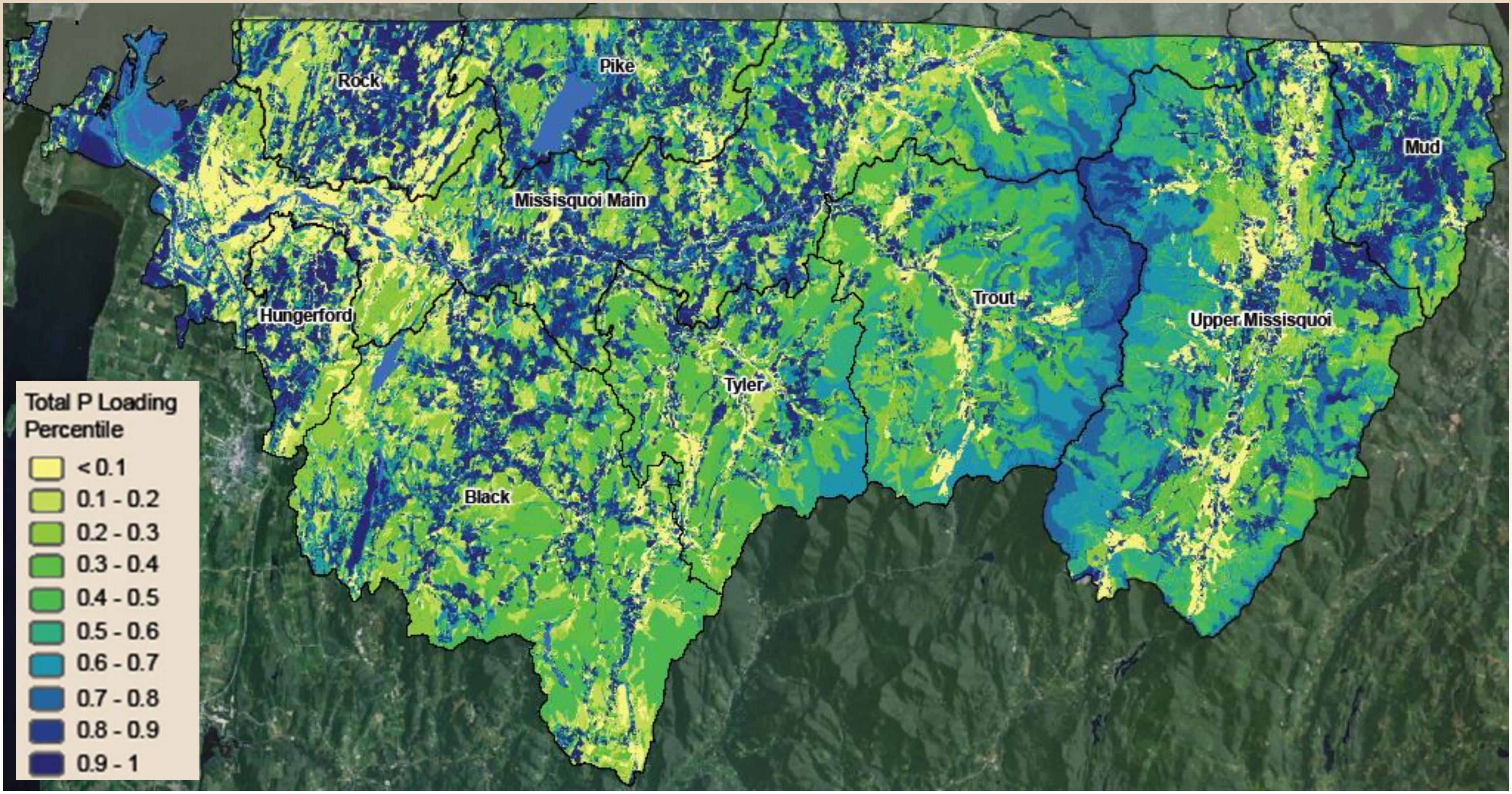
Model Application: Cumulative Area Distribution of Total Upland P Generated

- SWAT was run for 30 years.
- 57% of the total upland P is generated from 10% of the area.
- 74% of the total upland P is generated from 20% of the total area.
- 92% of the total upland P is generated from 50% of the total area.



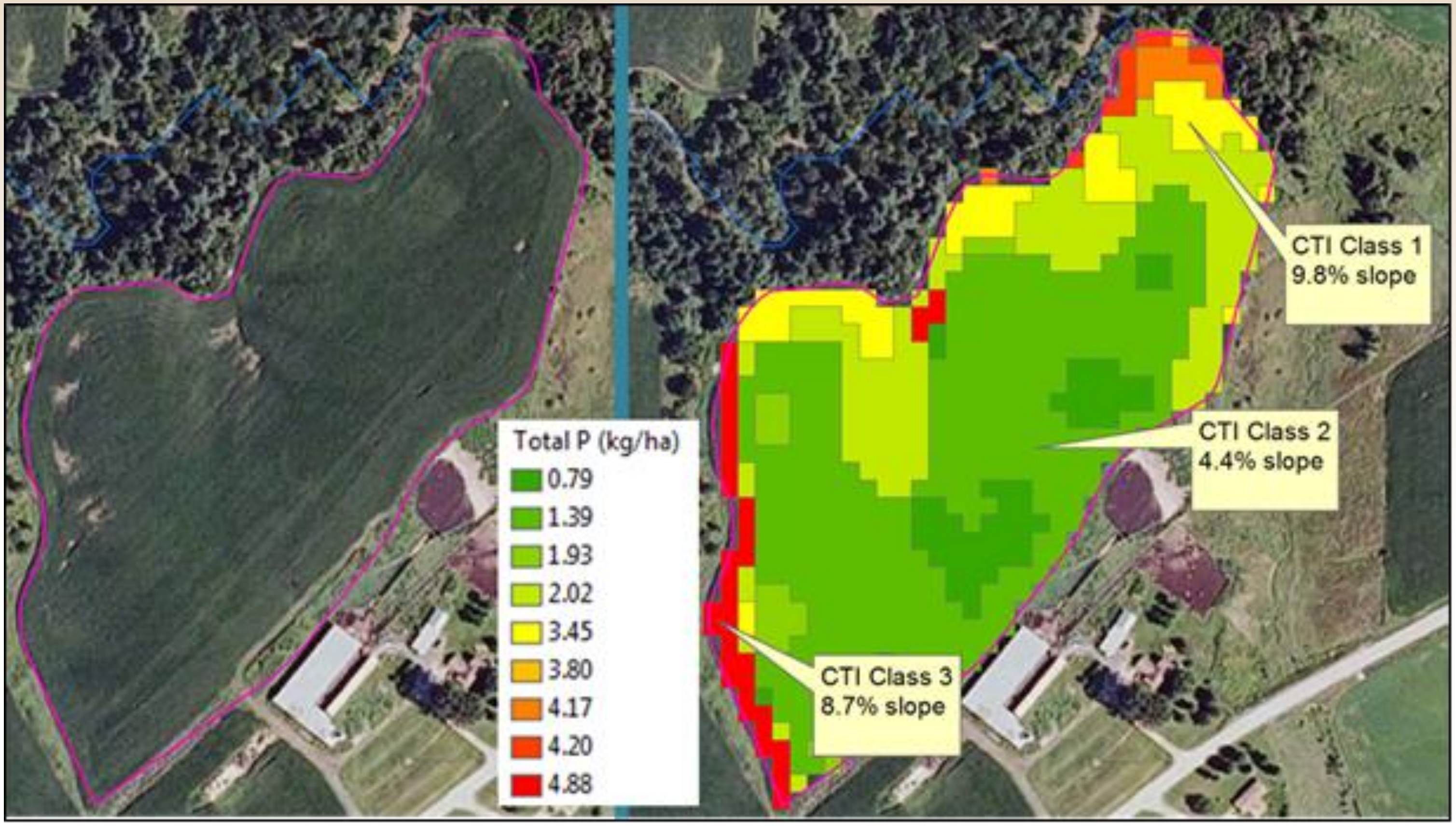
Model Application: Total P Load Ranking

- The percentile of the total P loading rate distribution (of all HRUs) was determined for each HRU.



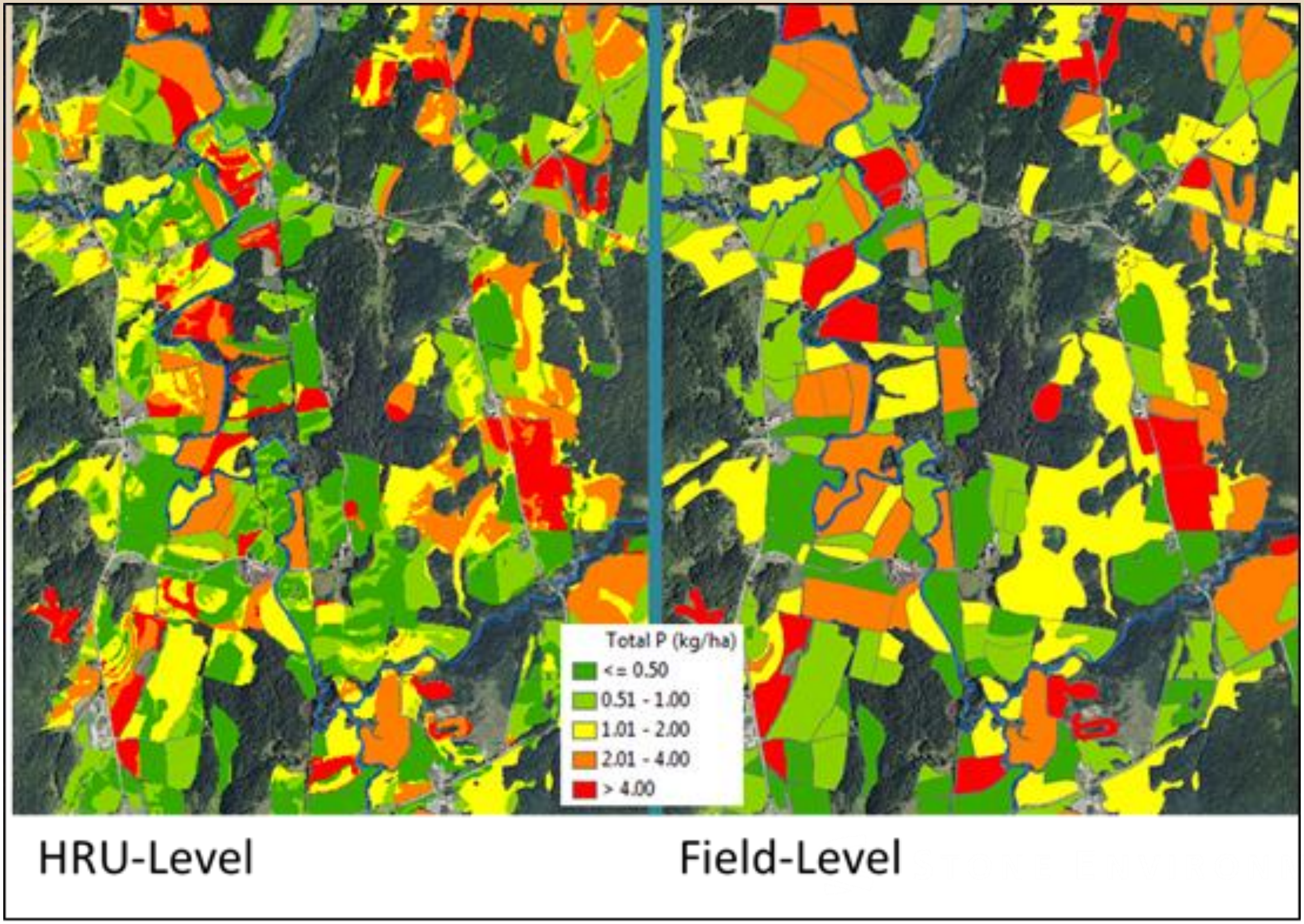
Model Application:
CSA HRU Level Results, Sub-Field Level

- Model results at the sub-field level may be used to identify critical sections of fields.
- Can help to determine specific locations for BMP implementation.



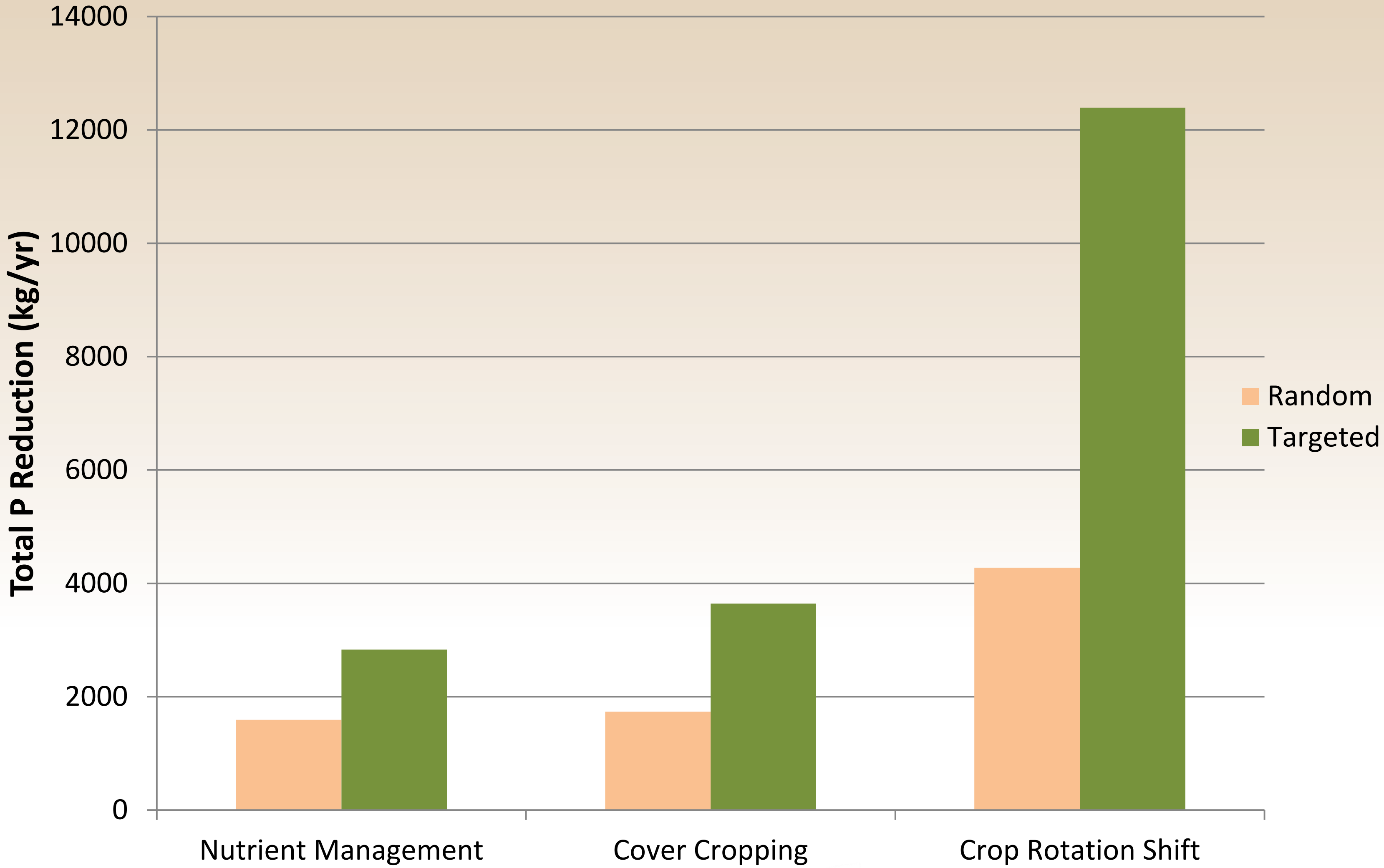
Model Application: CSA Aggregation to Field Level

- HRU aggregation to the field level allows ranking and prioritization of BMPs for individual fields.



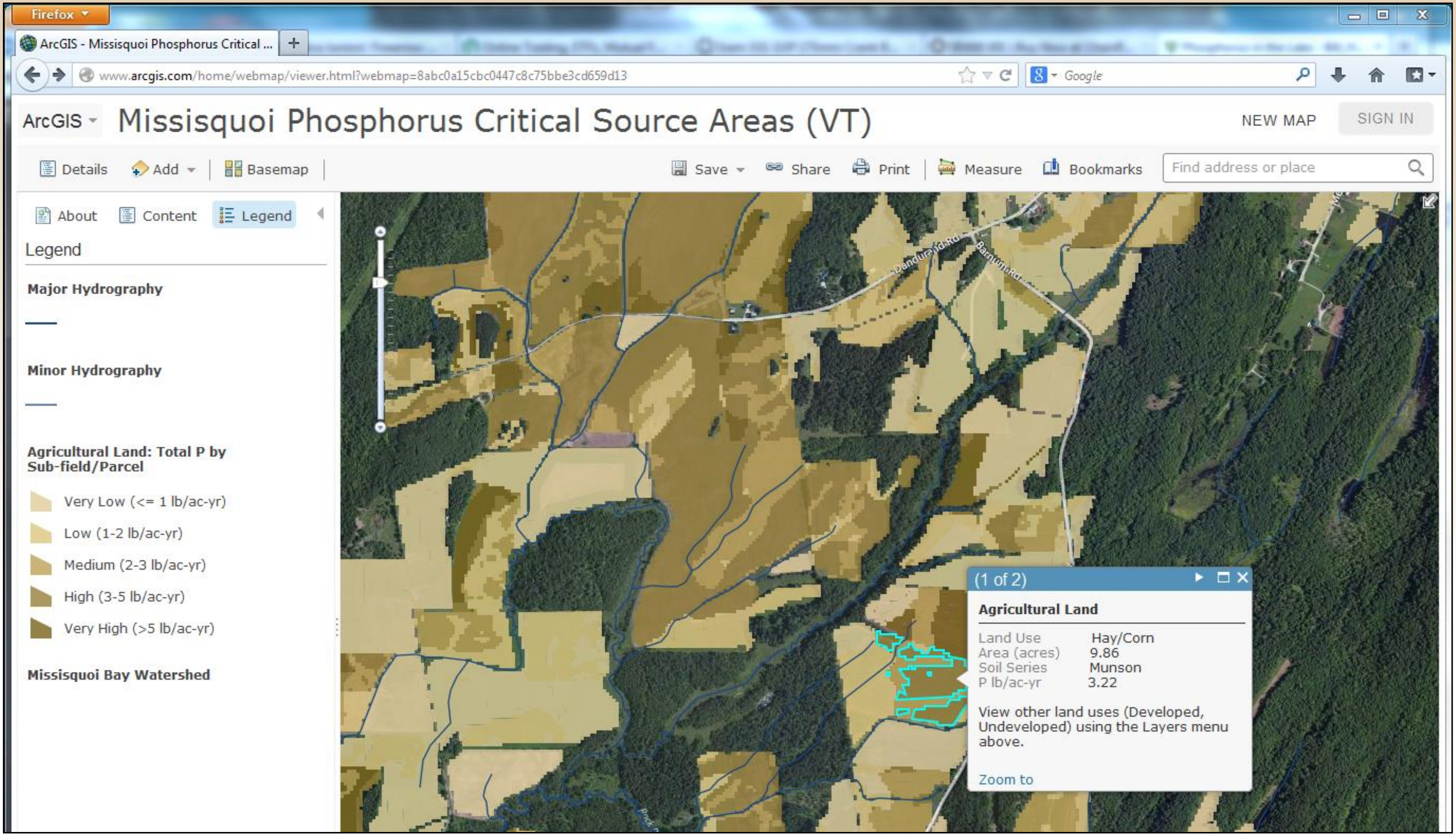
Model Application:
Evaluation of Watershed-Scale BMPs

- Targeted BMP implementation to 20% of the crop areas was 1.8 to 2.9 times more effective than random implementation.



Model Application:
Model Analysis via Online Mapping Tool

- Model inputs and results publically available via an ArcGIS Online map.



Summary and Conclusions

- An HRU delineation approach considering land use, soils, CTI and field boundaries was applied to enable sub-field level identification of phosphorus critical source areas.
- The incorporation of the CTI allowed landscape areas more prone to saturation excess runoff generation to be distinguished and independently parameterized.
- The curve number values for each HRU were adjusted higher or lower from the standard CN2 values based on their overall CTI cumulative distribution percentile.
- A comparison of random versus targeted BMP implementation demonstrated the advantages of the targeted approach.
- The modeling approach has allowed conservation planners to allocate finite mitigation funds to fields which will have the greatest benefit on the water quality of Lake Champlain.

References

- Beven, K.J. and Kirkby, M.J., 1976. Towards a simple physically-based variable contributing model of catchment hydrology. School Geogr., Univ. of Leeds, Leeds, Work. Pap. No. 154.
- Dunne, T., and Black, R. D. 1970. “Partial area contributions to storm runoff in a small New England watershed.” Water Resour. Res. 6:1296–1311.