Implications of Different Nutrient Load Estimation Techniques for Testing SWAT: An Example Assessment for the Boone River Watershed in North Central Iowa

Philip W. Gassman, CARD, Iowa State University, Ames, IA, USA

Keith Schilling & Calvin Wolter
Iowa Geological Survey, IIHR, Univ. of Iowa, Iowa City, IA, USA
& Iowa Dept. of Natural Resources, Des Moines, IA, USA

Steven K. Mickelson, Dept. of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA, USA

Funded in part by CenUSA Bioenergy (www.cenusa.iastate.edu/), a USDA-NIFA-AFRI-coordinated agricultural project (Project #: 20116800530411-BEI-KLI).

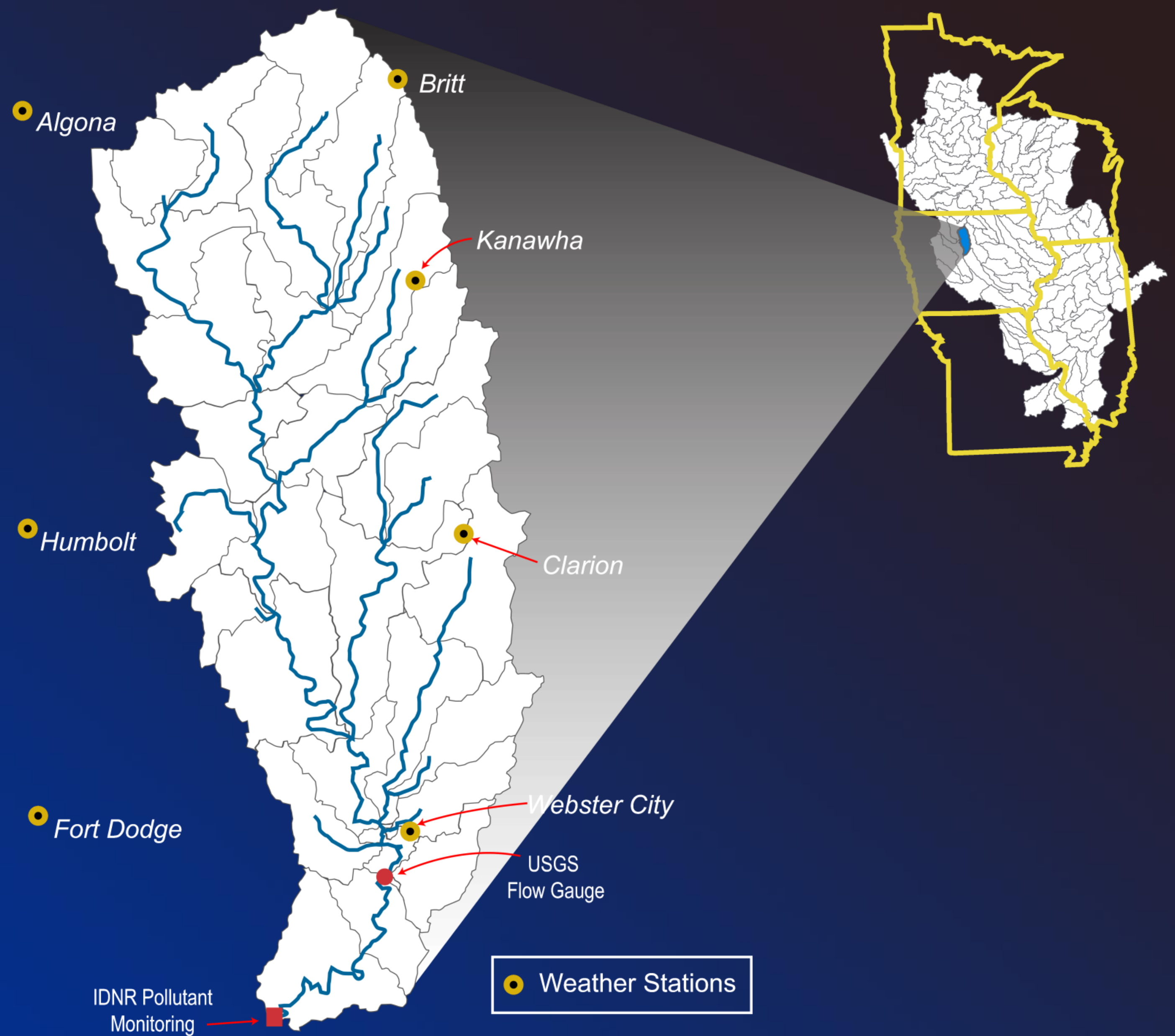
Overview of Presentation

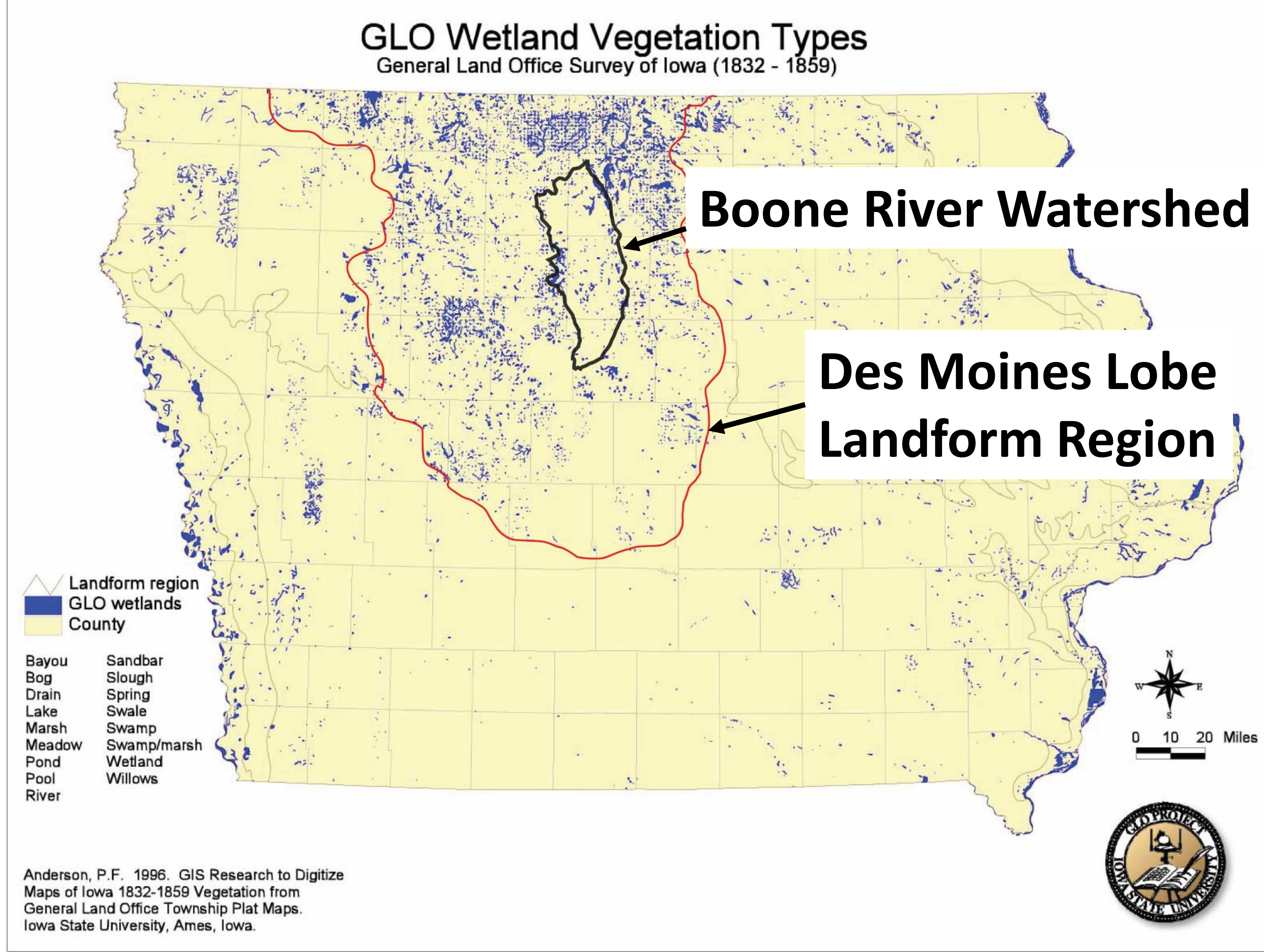
- Description of the Boone River Watershed (BRW) and Des Moines Lobe region
- SWAT model structure including nutrient inputs
- Pollutant load estimation issues / model testing results
- Conclusions

Boone River Watershed

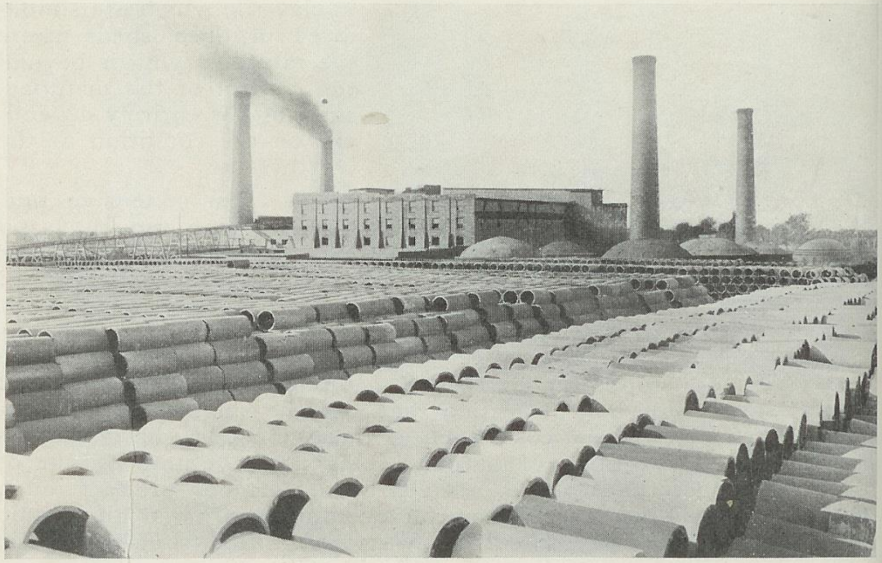
- 2,370 km^2 in parts of six counties in north central Iowa
- Des Moines Lobe landform region; southern portion of North American Prairie Pothole region
- Generally level topography; heavily tile drained
- Dominated by crop production

Boone River Watershed





GLO Wetland Vegetation Types
General Land Office Survey of Iowa (1832 - 1859)
Boone River Watershed
Des Moines Lobe
Landform Region
Landform region
GLO wetlands
County
Bayou
Bog
Drain
Lake
Marsh
Meadow
Pond
Pool
River
Sandbar
Slough
Spring
Swale
Swamp
Swamp/marsh
Wetland
Willows
N
W
E
S
0 10 20 Miles
GLO PROJECT
IOWA STATE UNIVERSITY
Anderson, P.F. 1996. GIS Research to Digitize
Maps of Iowa 1832-1859 Vegetation from
General Land Office Township Plat Maps.
Iowa State University, Ames, Iowa.

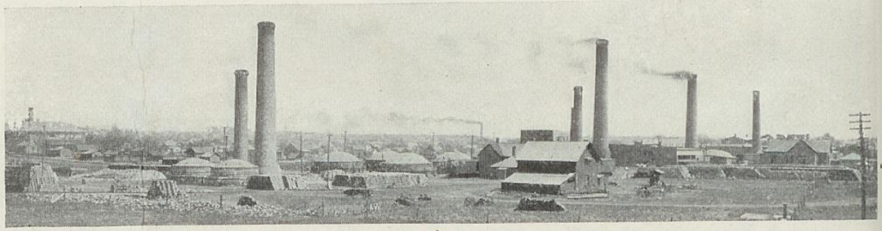


One reason why we can always give you prompt shipment.

5. Our large resources and financial reliability, and our over thirty years of reputation for fair dealing, insure that you will get nothing but the highest class product, and the squarest possible treatment from us.

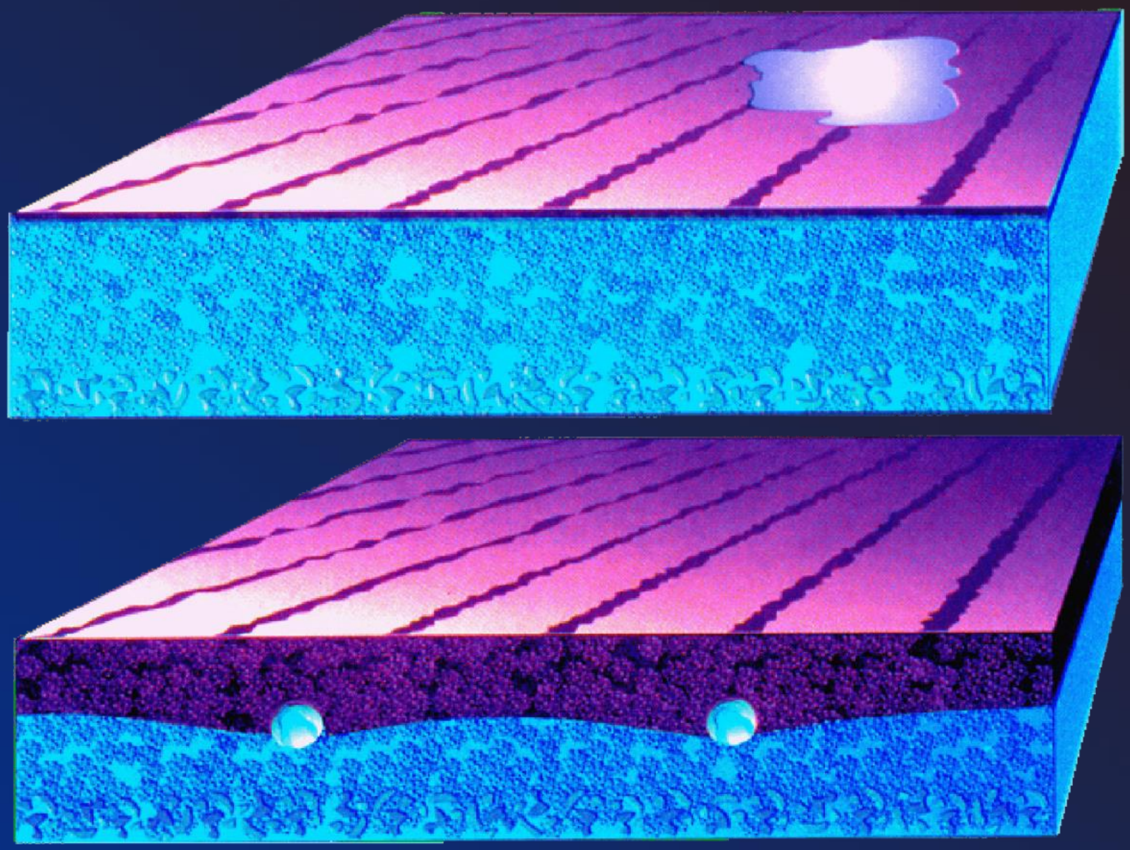
MASON CITY BRICK AND TILE CO.

Mason City, Iowa.



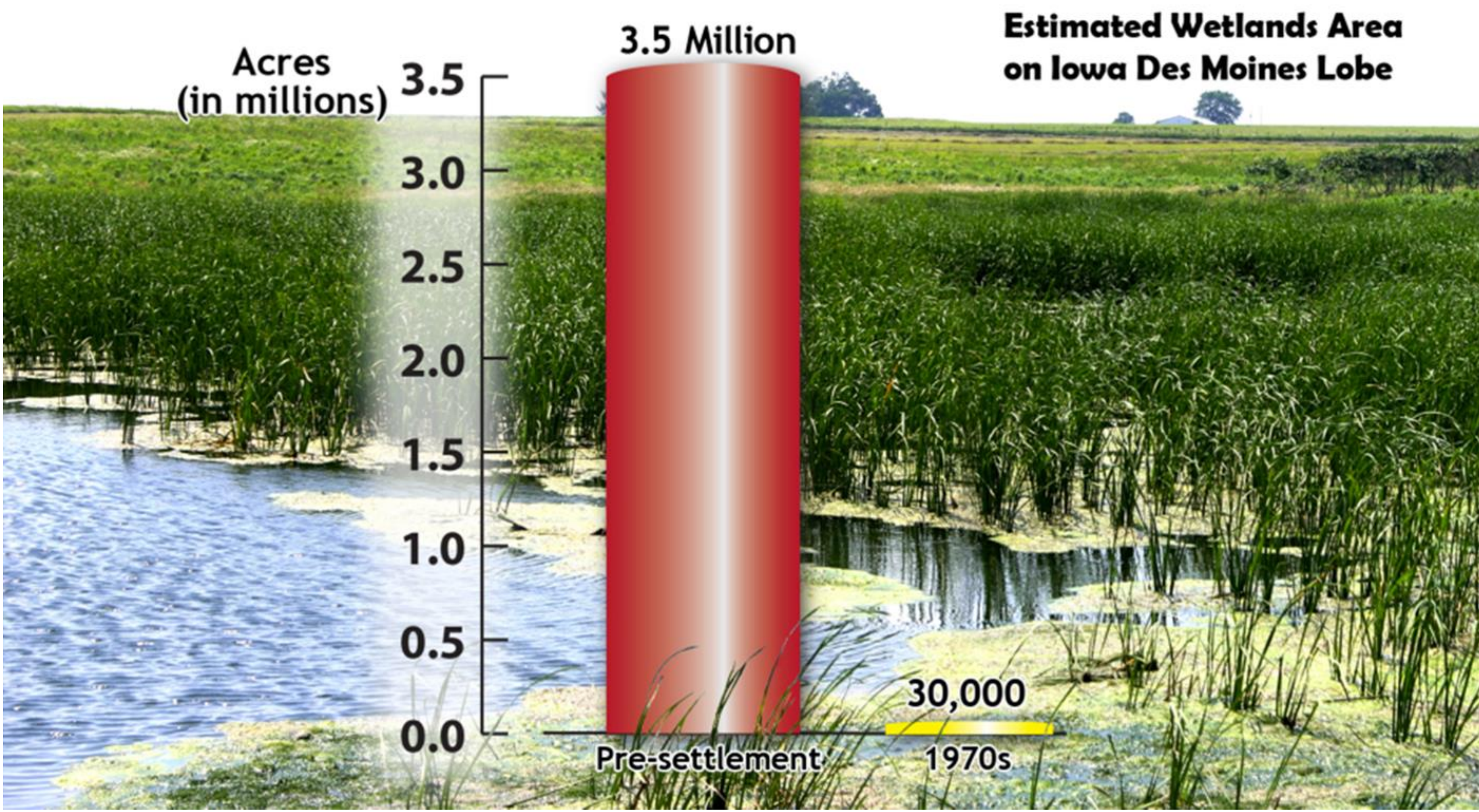
A bird's-eye view of one of our factories.

Effects of Tile Drainage on Soil Water



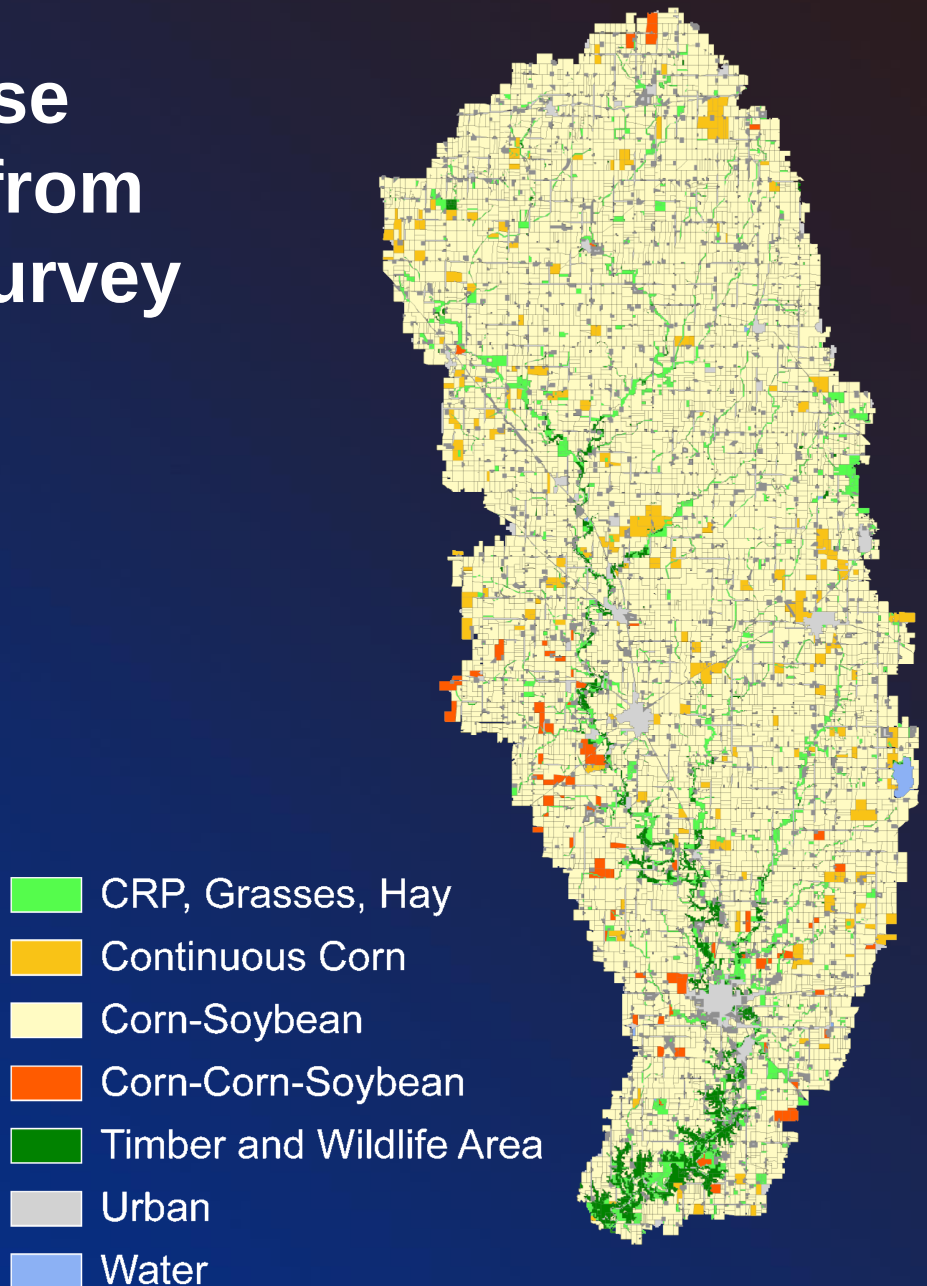
Adapted from: Zucker, L.A. and L.C. Brown (eds.). 1998. Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest. Ohio State University Extension Bulletin 871. The Ohio State University.

Wetland Loss in the Des Moines Lobe Region: 99%

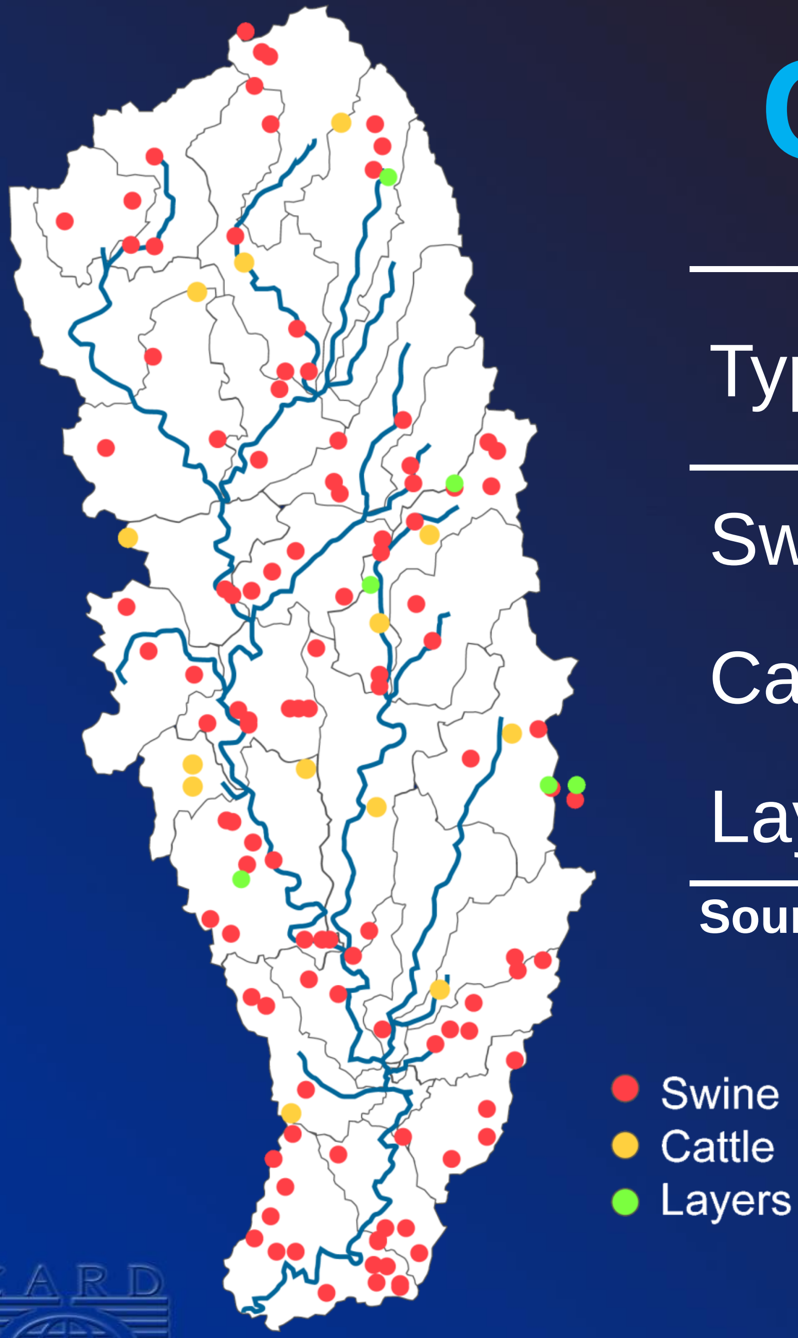


Source: Iowa Learning Farms. 2016. Wetlands: By the numbers. https://iowalearningfarms.wordpress.com/2016/05/17/wetlands-by-the-numbers/

2005 Land Use Determined from Field-level Survey



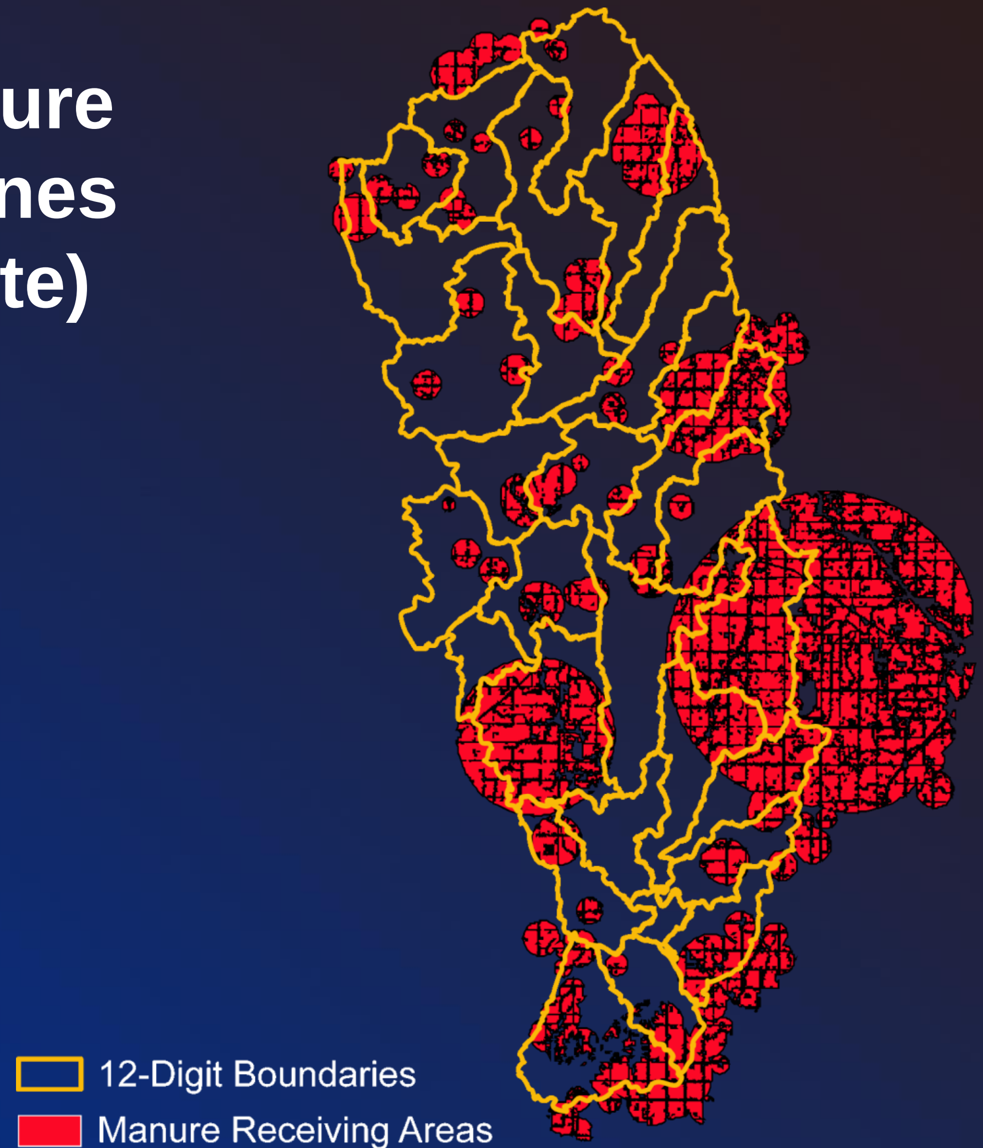
CAFOs



Type	Total operations	Total head
Swine	109	481,448
Cattle	13	4,265
Layers	6	6,962,112

Source: 2005 IDNR CAFO data

Estimated Manure Application Zones (112 kg/ha N rate)



Data generated by C. Wolter, Iowa Dept. of Natural Resources, Des Moines, IA; Software developed by D. James, USDA -ARS, Ames, IA

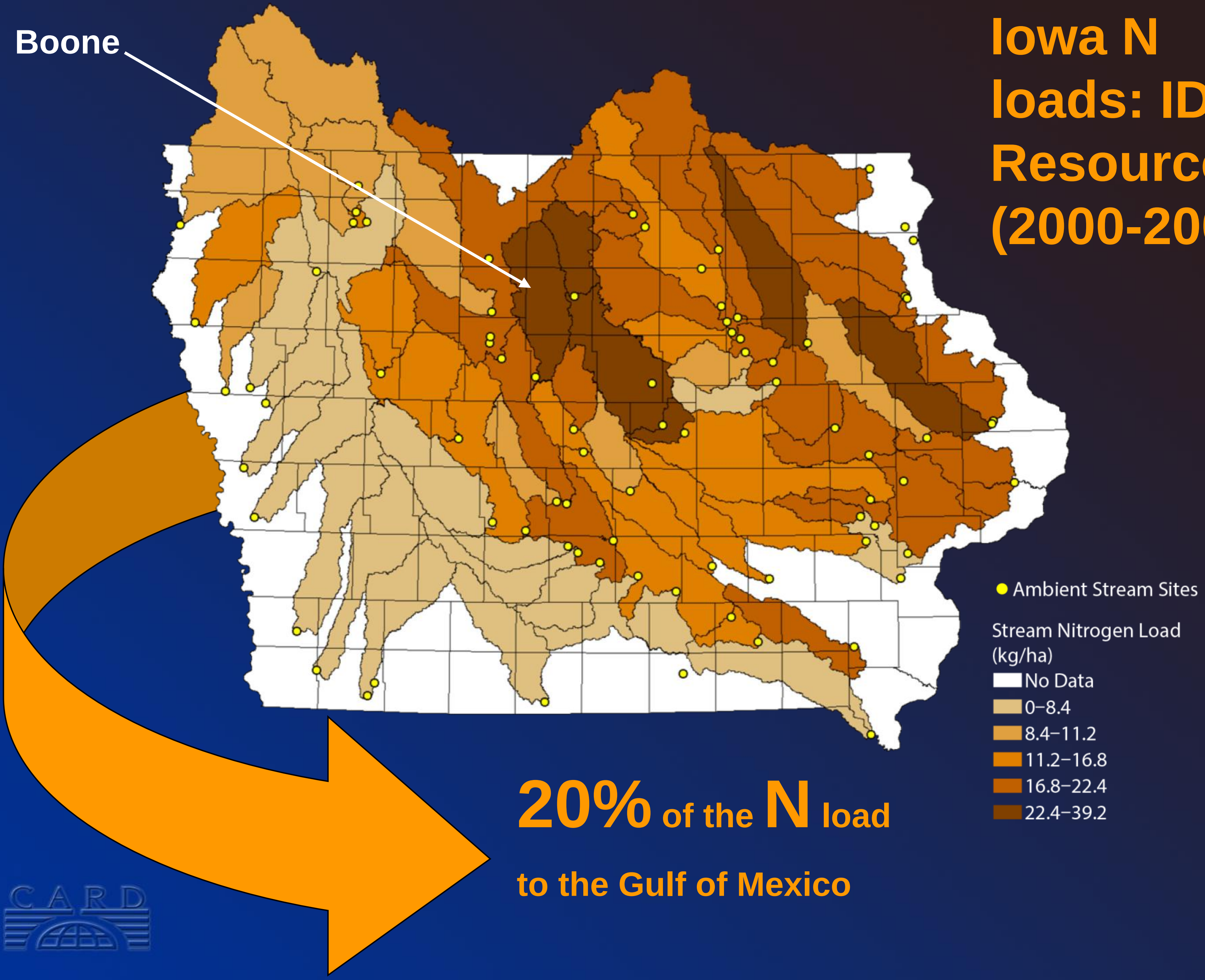
Nutrient Applications

- N fertilizer rates on corn not receiving livestock manure
  - corn after soybean:
    - spring: 172 kg/ha
    - fall: 183 kg/ha
  - corn after corn: 196 kg/ha

  - P_2O_5 fertilizer rate for corn: 49 kg/ha

- Manure assumptions less straightforward
  - 80% applied on corn & 20% on soybean
    - N rate: 190 kg/ha
    - P rate: 70 kg/ha
  - 50% of manured corn also fertilized

Iowa N loads: IDNR Resources (2000-2002)



20% of the N load

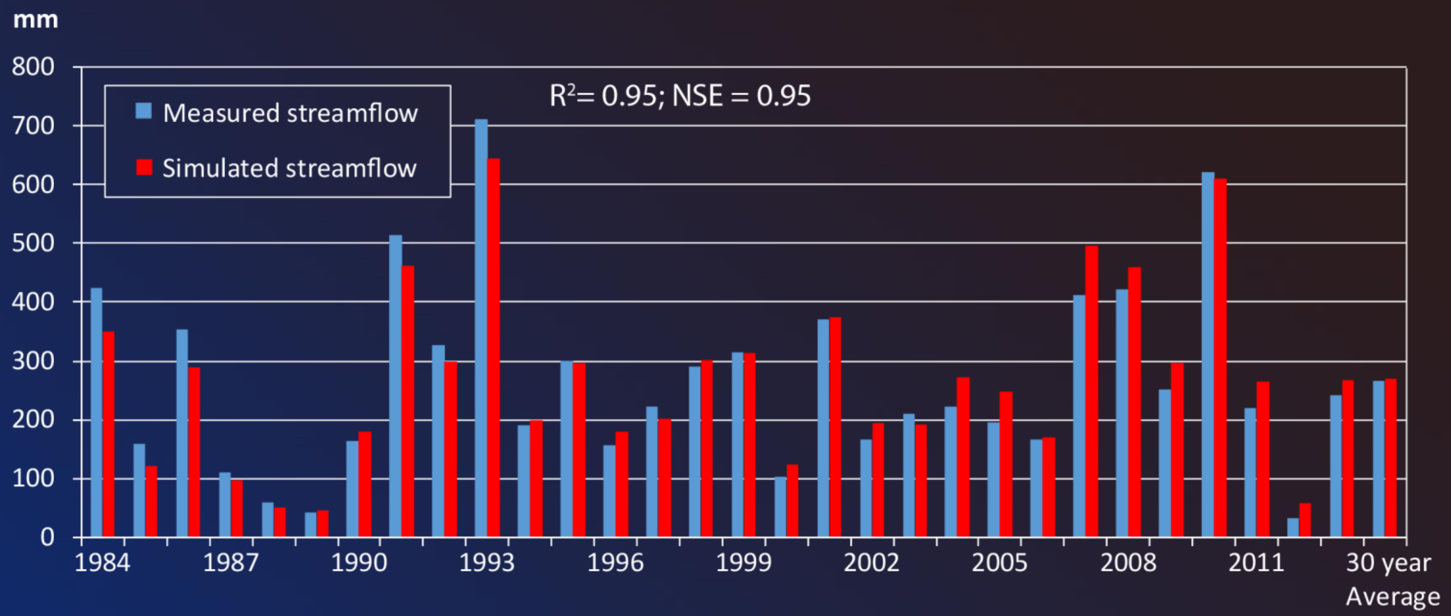
to the Gulf of Mexico

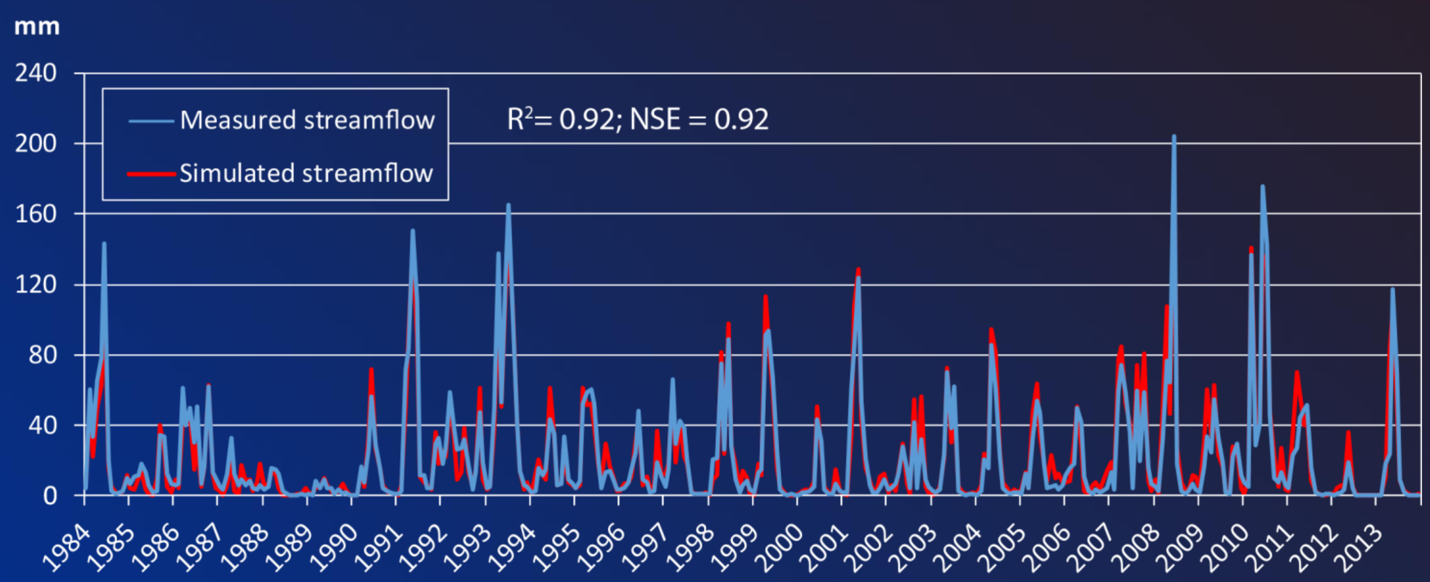
SWAT Version & Simulation Approach

- SWAT version 2012; Release 615
- Simulation period: 1984 to 2013
- Used ET-based Runoff Curve Number Approach
- Account for tile drainage (original method)
  - depth of 1200 mm (~4 ft)
- Tile drains simulated for cropland <2% slope
  – ~80% of the cropland
  – 2012 USDA-NASS Census: ~70% for six counties

30-Year Streamflow Comparison (1984-2013)

Initialization years: 1982 & 1983



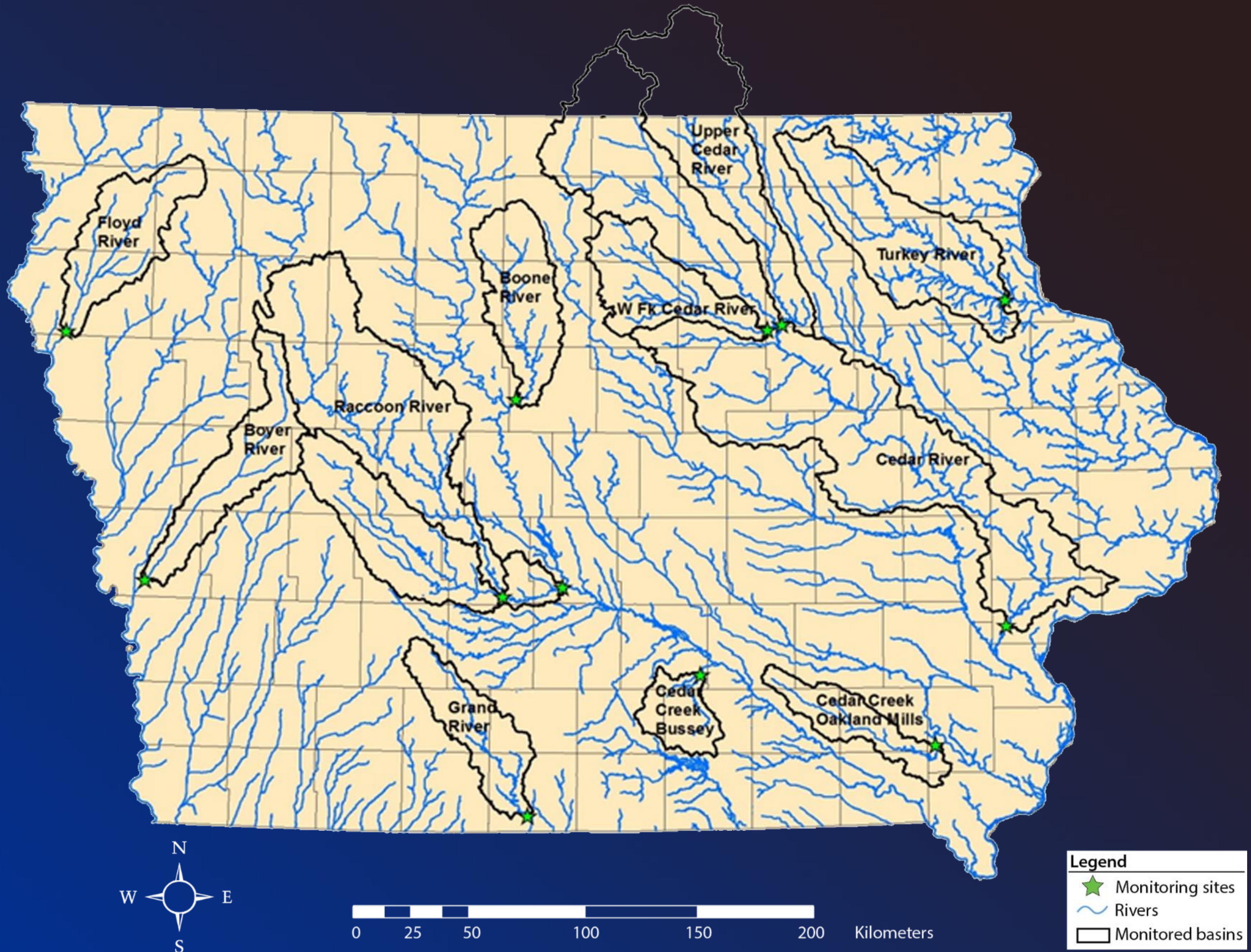


USGS LOADEST Problems

- **Stenback et al. 2011. Rating curve estimation of nutrient loads in Iowa rivers. Journal of Hydrology 396: 158- 169. DOI: 10.1016/j.jhydrol.2010.11.006.**

- http://water.usgs.gov/software/loadest/

IMPORTANT NOTE: LOADEST can produce biased load estimates when the selected model is a poor representation of the relationship between load and the explanatory variables. Problems with load bias may be identified through careful analyses of model residuals. LOADEST has therefore been modified since its initial release to include several features that facilitate residual analysis and bias identification. This updated version of the software was placed on the web site on March 27, 2013 …..



Source: Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. Journal of Soil Water Conservation (accepted).

Description of Nitrate Load Estimation Methods

Load Estimation Method	Description
Linear interpolation	Fill concentration gaps between measured values by a straight line; multiply by streamflow to obtain loads
Average monthly values	Average monthly streamflow multiplied by a monthly nitrate concentration
AutoBeale method	Annual load is computed as a function of concentrations and an adjusted flow ratio

Source: Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).

Description of Nitrate Load Estimation Methods

Load Estimation Method	Description
Cokriging	Correlation of measured NO3-N loads to daily discharge, to improve interpolation
LOADEST	Seven parameter regression model; uses continuous stream flow to estimate loads
WRTDS	Regression method that accounts for discharge, seasonality, long-term trend, and a random component

Source: Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).

BRW Pollutant Monitoring Data

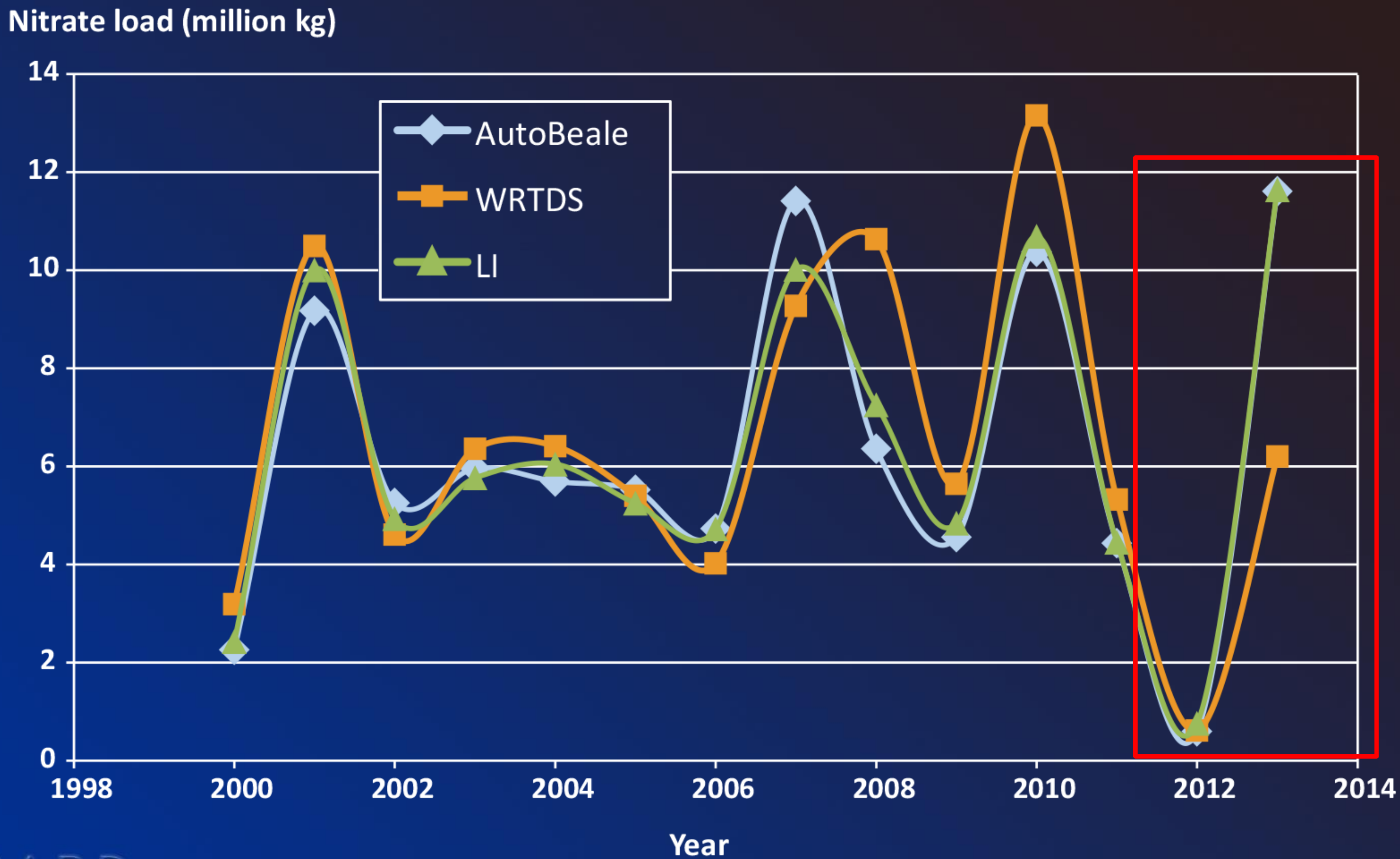
- Collected near watershed outlet (2000 to 2013)
- Monthly grab samples at best (sometimes periods of multiple months between samples)
- Just calibration was performed for pollutant loss/transport testing

Estimated Nitrate Loads at Boone Outlet

Load Estimation Method	Estimated Daily Average Nitrate Load (kg)
Linear interpolation	17,848
Average monthly values	13,626
AutoBeale method	16,517
Cokriging	24,652
LOADEST	40,009
WRTDS	17,376

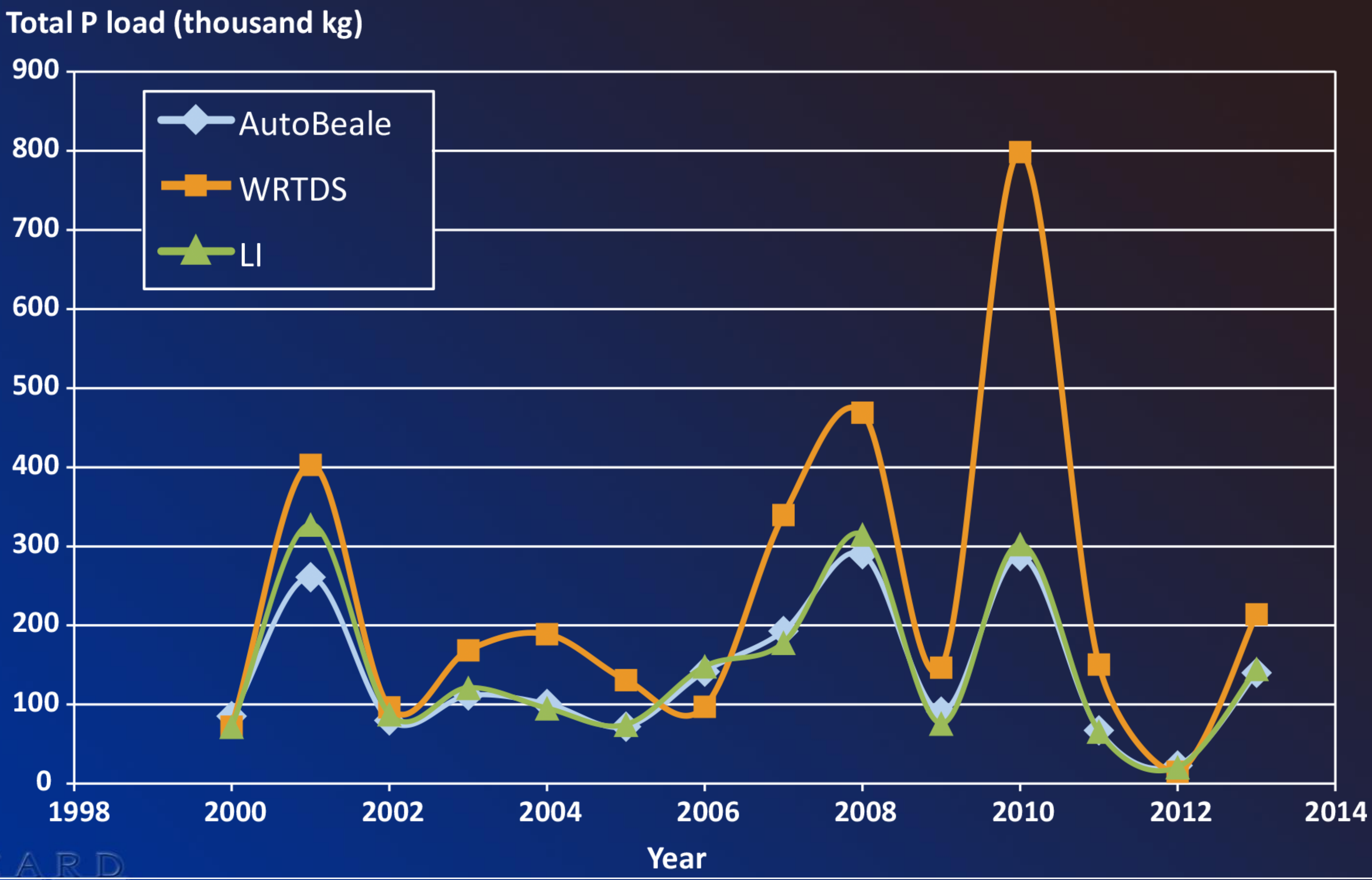
Source: Schilling et al. 2015. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepteed).

Estimated Nitrate Loads at Boone Outlet



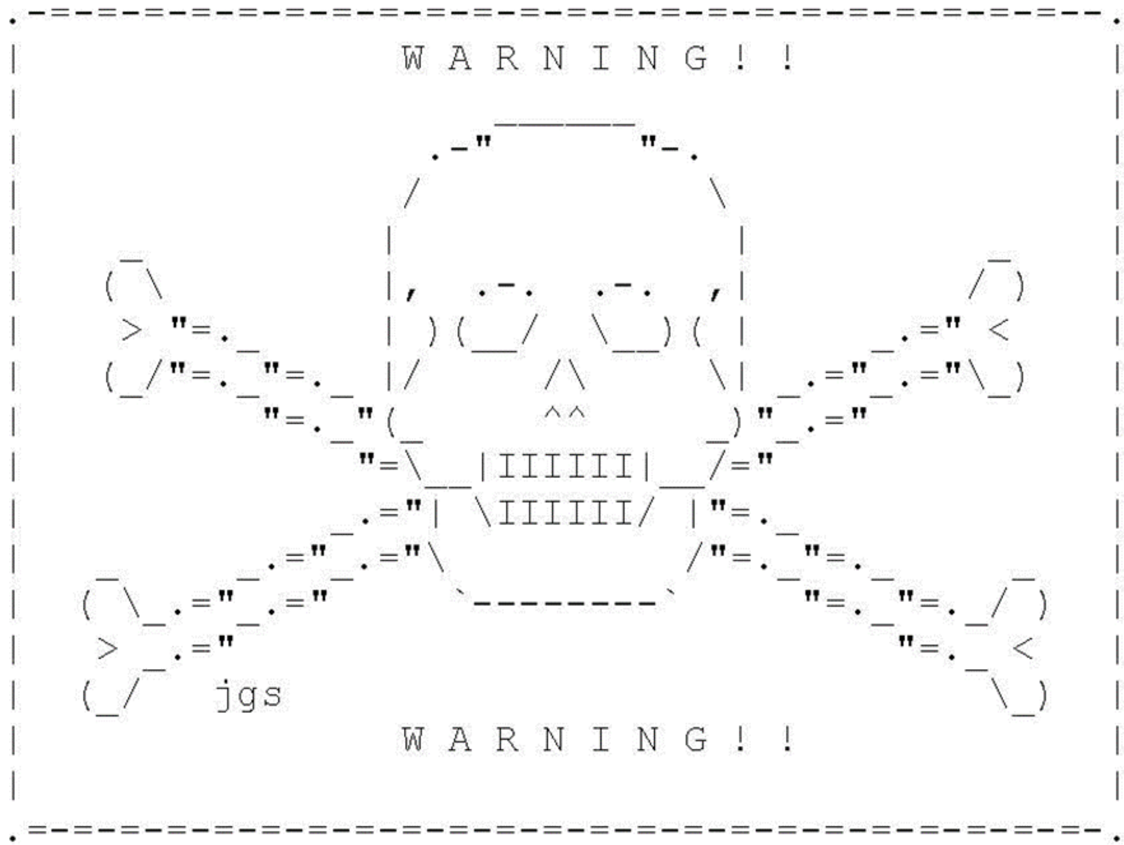
Data generated by C. Wolter, Iowa Deptartment of Natural Resources, Des Moines, IA

Estimated Total P Loads at Boone Outlet



Data generated by C. Wolter, Iowa Deptartment of Natural Resources, Des Moines, IA

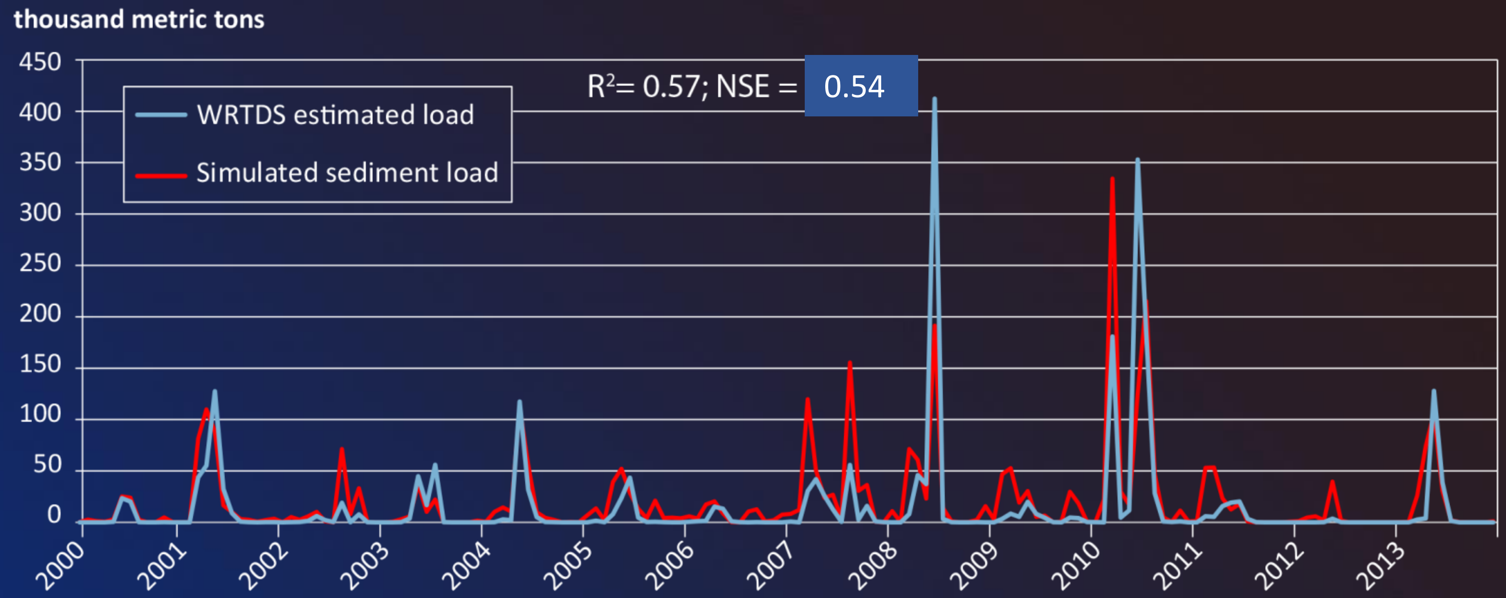
LOADEST Sediment Results were also Excessively Biased



IMPORTANT WARNING:

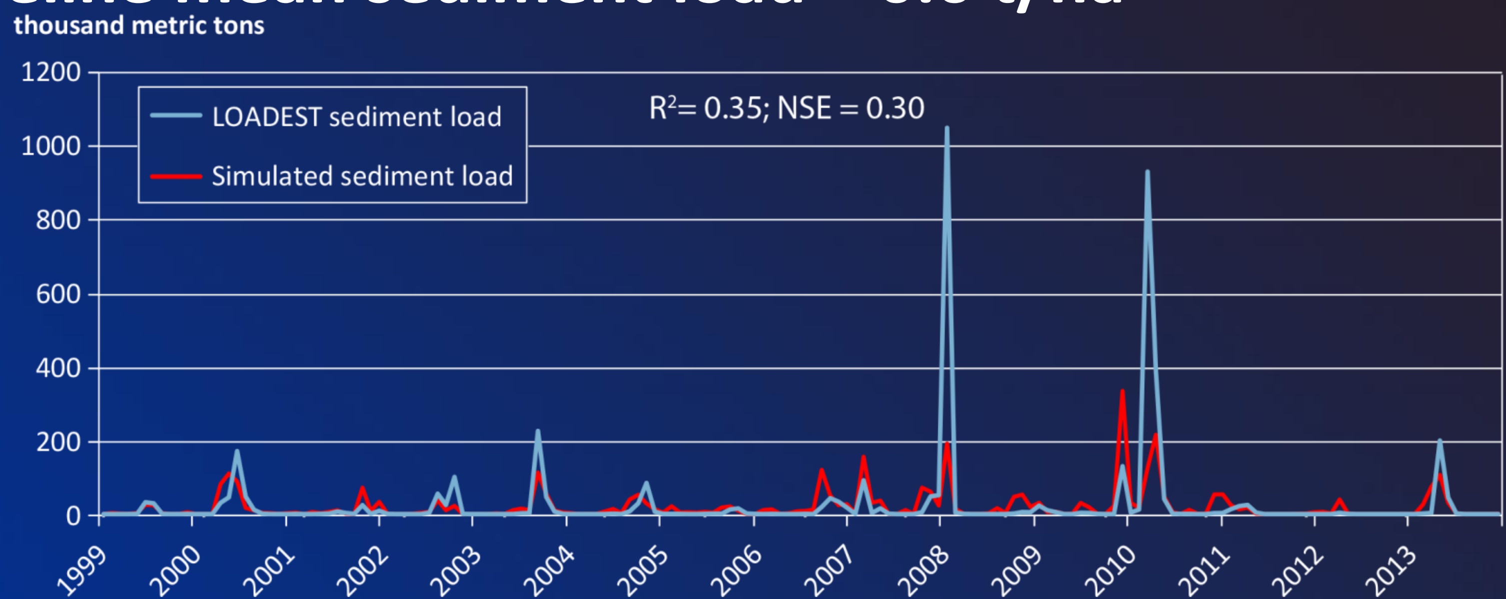
Load Bias (Bp) Exceeds + or - 25%
THE CALIBRATED MODEL SHOULD NOT BE USED FOR LOAD ESTIMATION

WRTDS-based SWAT Result

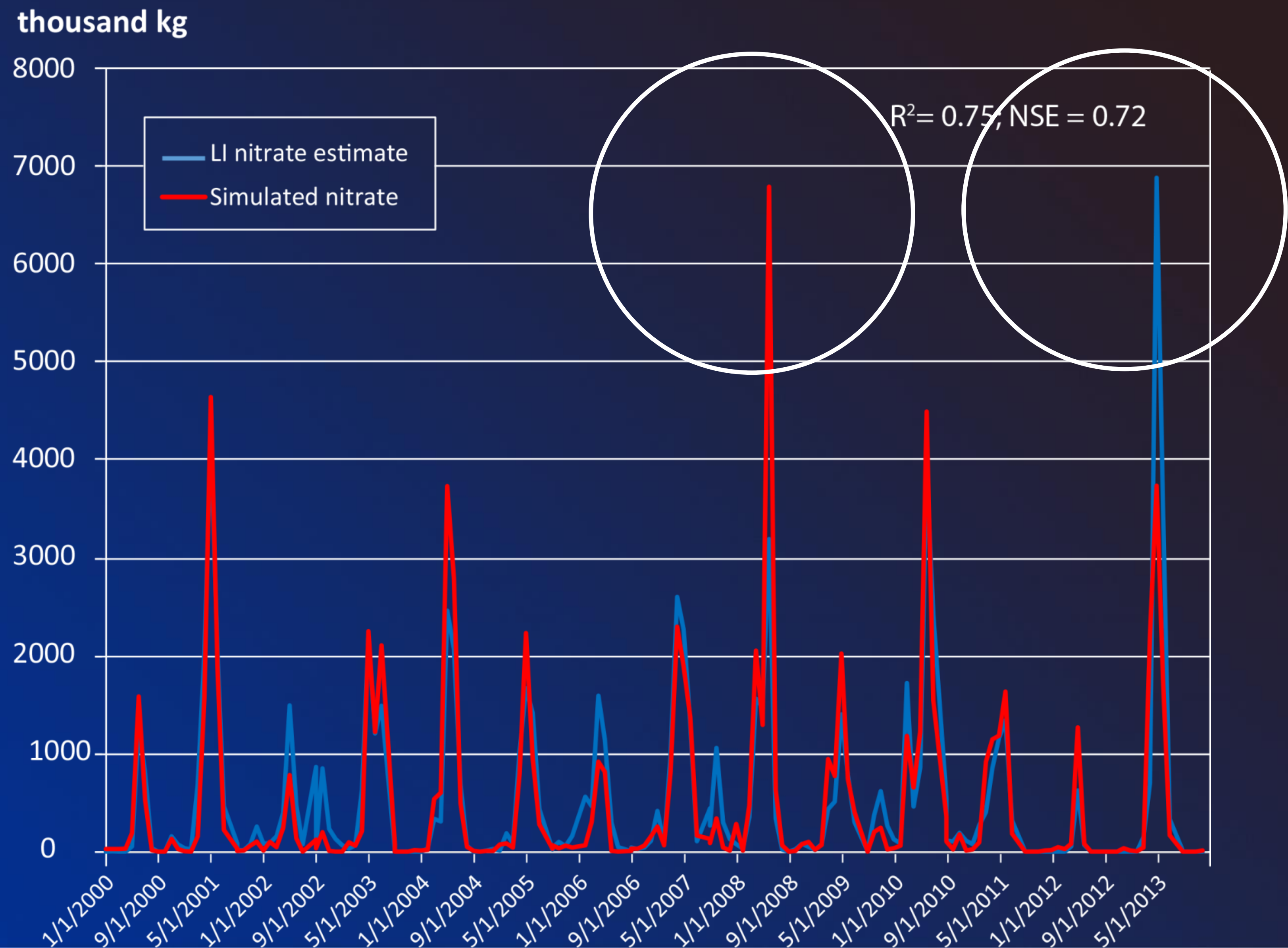


Baseline mean sediment load = 0.6 t/ha

LOADEST-based SWAT Result



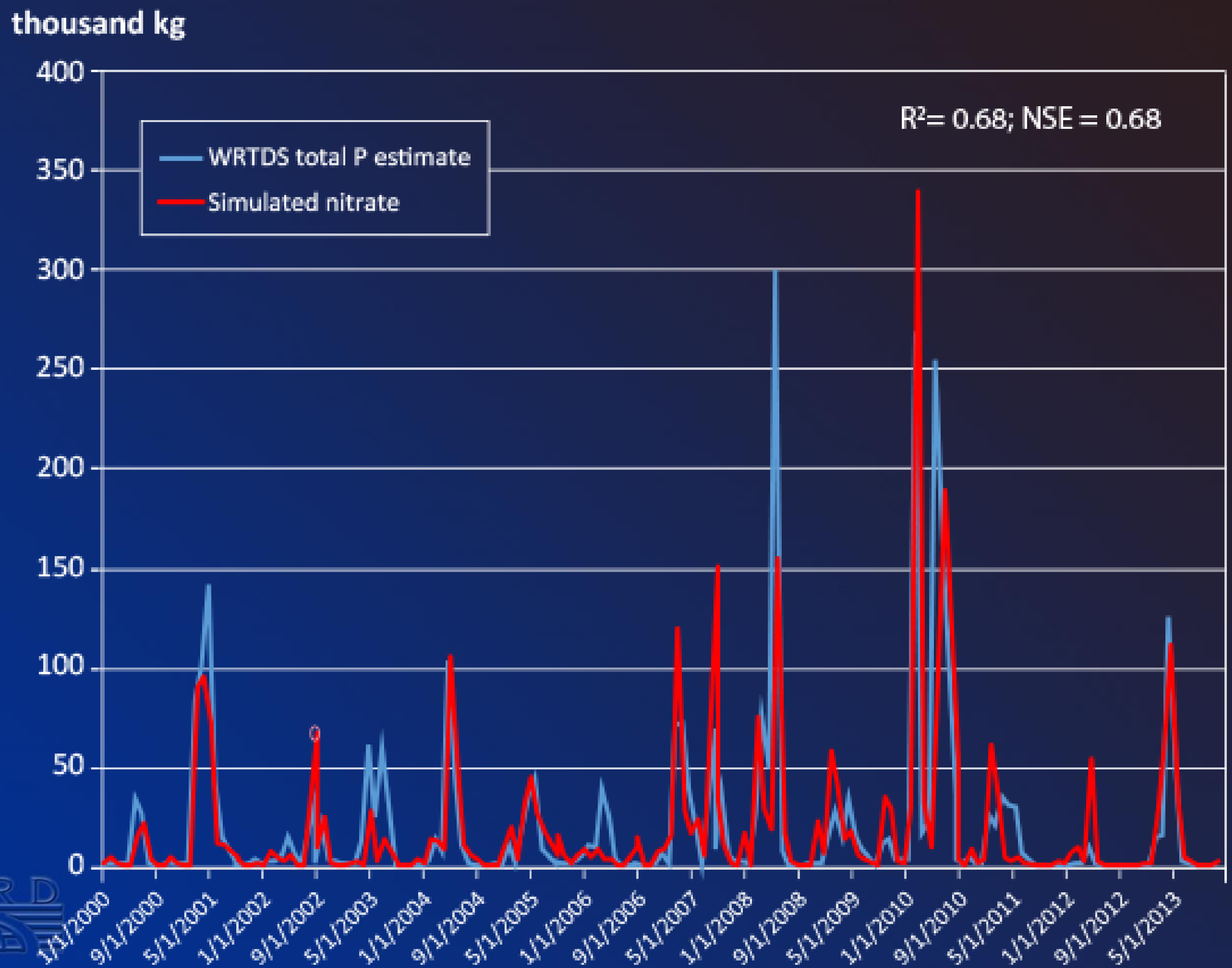
Simulated vs. "Measured" Nitrate Loads (Measured Loads Based on LI Method)



CARD

Simulated vs. "Measured" Total P Loads

(Measured Loads Based on WRTDS Method)



CARD

Conclusions

- LI and WRTDS provided most accurate nitrate and total P load estimates, respectively
  -SWAT captured most of the estimated load trends
- BRW sediment load estimates have bias problems
  -but sediment loads are relatively low (mean = .6 t/ha)
- LOADEST severely overestimated nitrate loads
- Will investigate comparisons with nitrate sensor data as part of the ongoing research