SWAT Model Overview and Application in the Upper Mississippi

Jeff Arnold
USDA-ARS - Temple, Texas

Model Philosophy

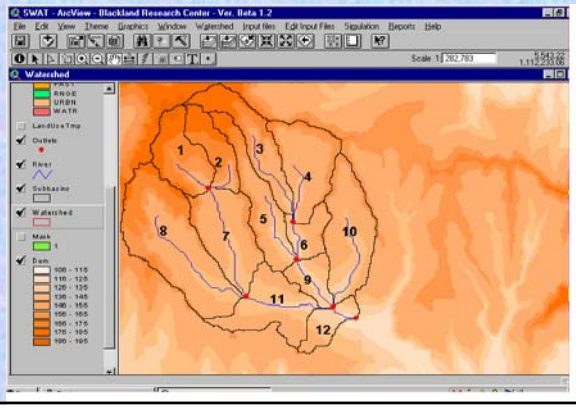
- Readily available input – Physically based
- Computer efficient
- Comprehensive – Process Interactions
- Simulate Management

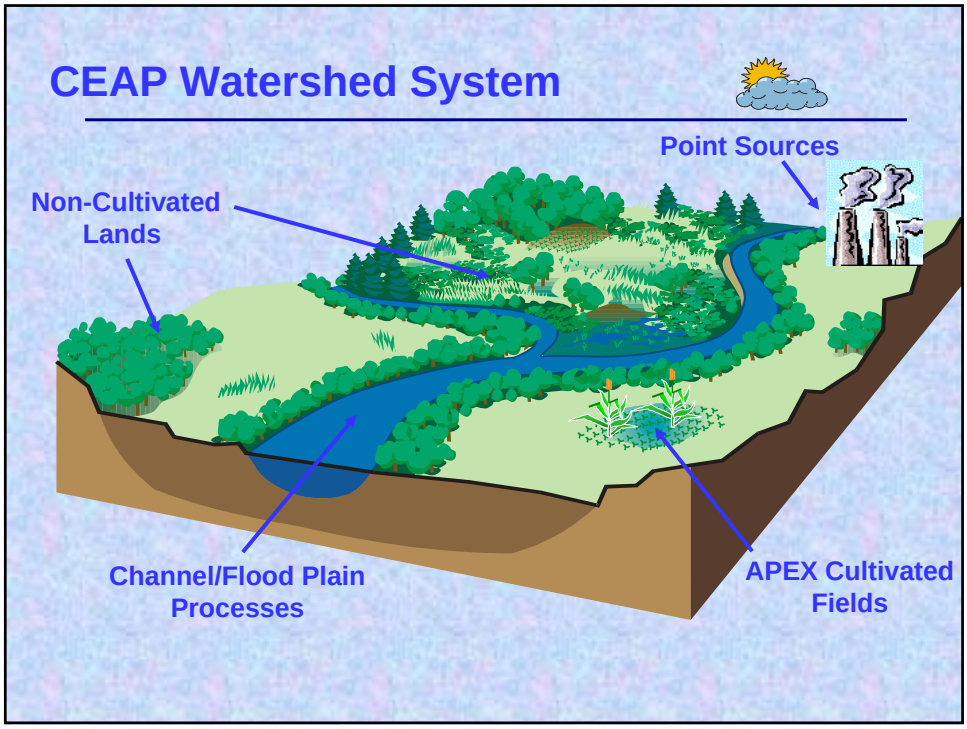
General Description

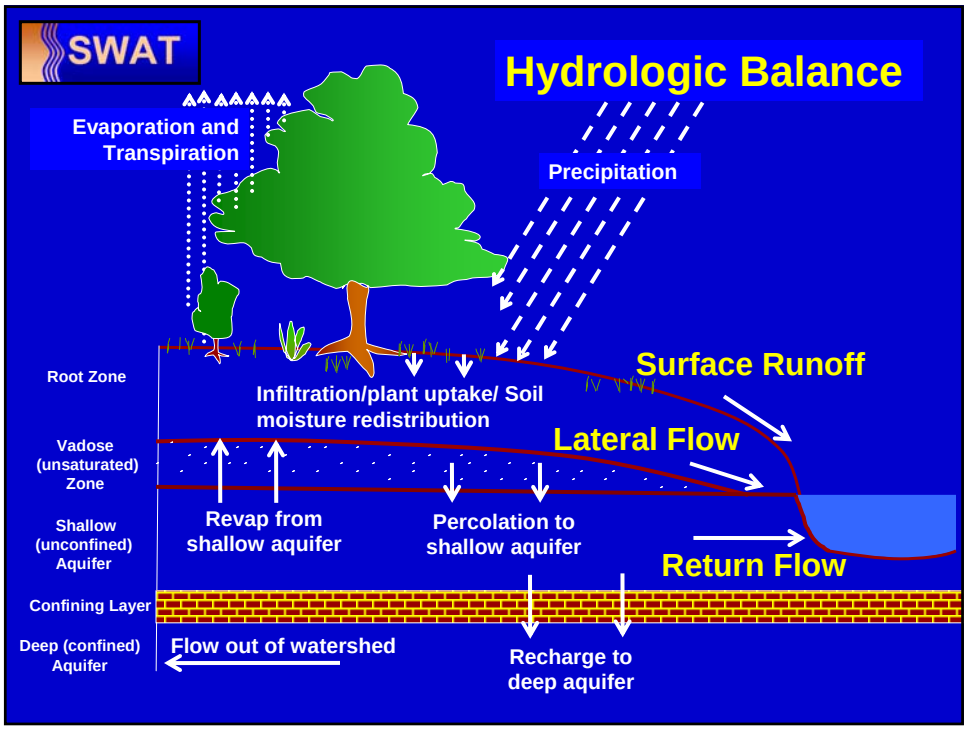
- Continuous Time
  - Daily Time Step (Sub-hourly)
  - One Day ⟶ Hundreds of Years
- Distributed Parameter
  - Unlimited Number of Subwatersheds
- Comprehensive – Process Interactions
- Simulate Management

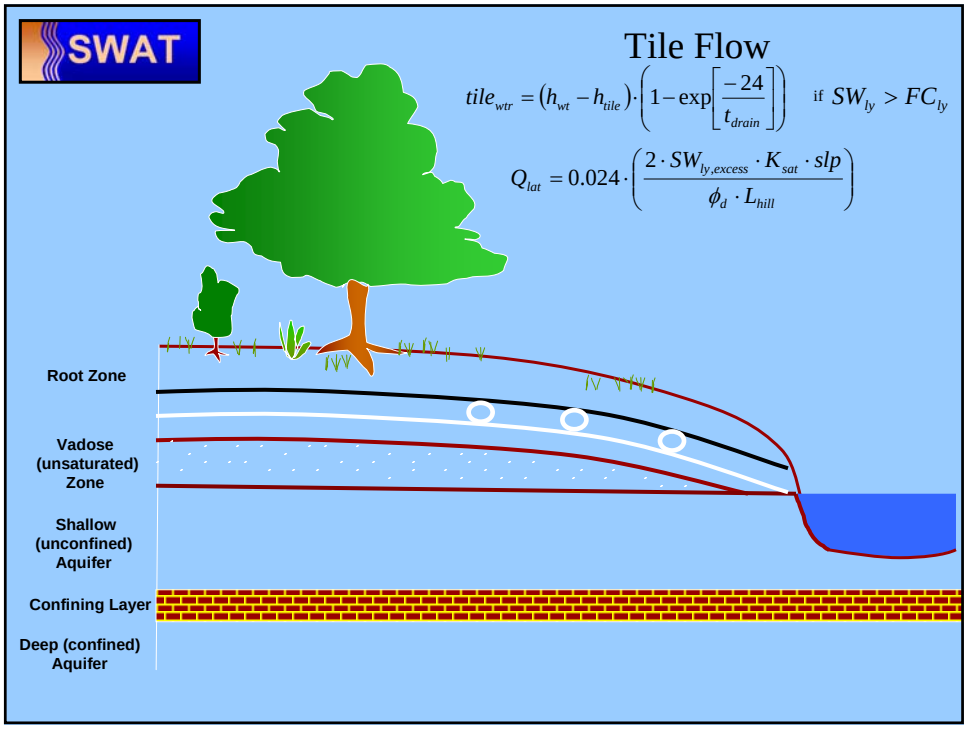
Possible Configurations

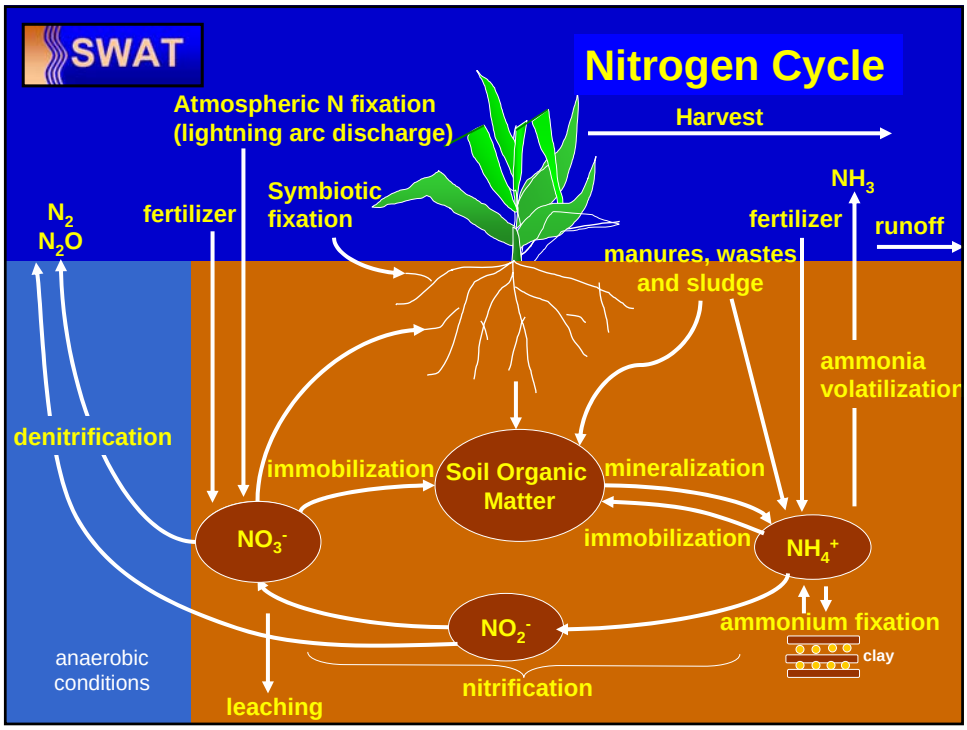
- Subwatersheds
- Hydrologic Response Units
- Output from other Models - APEX, SWAT
- Point Sources - Treatment Plants

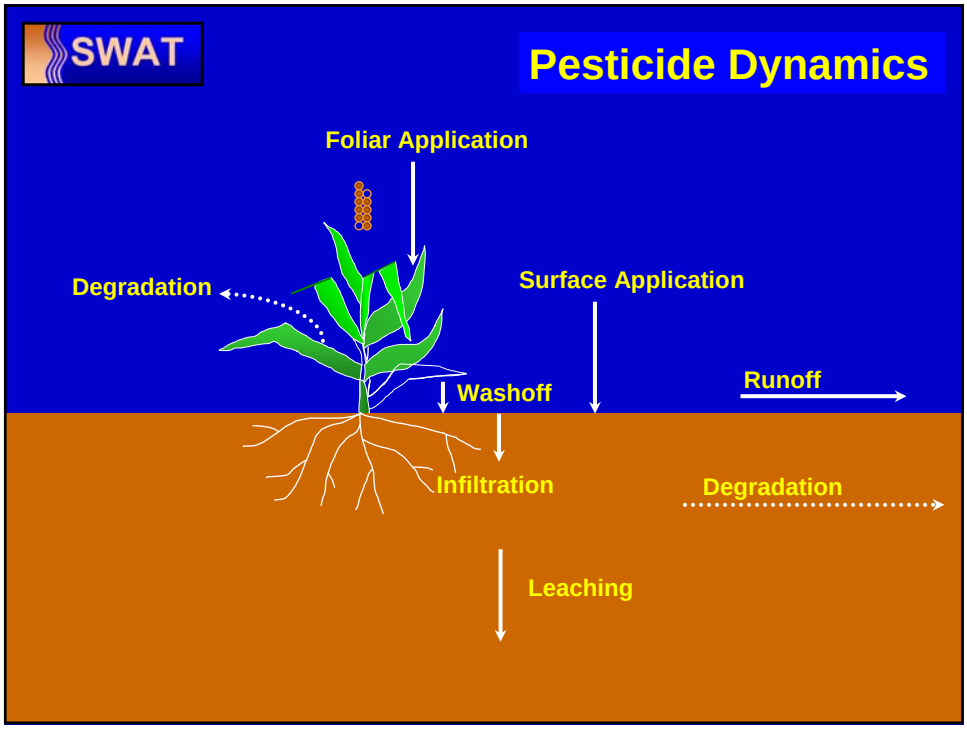



CEAP Watershed System
Point Sources
Non-Cultivated Lands
Channel/Flood Plain Processes
APEX Cultivated Fields


SWAT
Hydrologic Balance
Evaporation and Transpiration
Precipitation
Surface Runoff
Root Zone
Infiltration/plant uptake/ Soil moisture redistribution
Lateral Flow
Vadose (unsaturated) Zone
Shallow (unconfined) Aquifer
Revap from shallow aquifer
Percolation to shallow aquifer
Return Flow
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer


SWAT
Tile Flow
$tile_{wtr} = (h_{wt} - h_{tile}) \cdot \left(1 - \exp\left[\frac{-24}{t_{drain}}\right]\right)$ if $SW_{ly} > FC_{ly}$
$Q_{lat} = 0.024 \cdot \left(\frac{2 \cdot SW_{ly,excess} \cdot K_{sat} \cdot slp}{\phi_d \cdot L_{hill}}\right)$
Root Zone
Vadose (unsaturated) Zone
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer


SWAT
Nitrogen Cycle
Atmospheric N fixation (lightning arc discharge)
Harvest
N_2
N_2O
fertilizer
Symbiotic fixation
NH_3
fertilizer
runoff
manures, wastes and sludge
ammonia volatilization
denitrification
immobilization
Soil Organic Matter
mineralization
immobilization
NO_3^-
NH_4^+
NO_2^-
ammonium fixation
clay
anaerobic conditions
leaching
nitrification



SWAT

Management

- Crop Rotations
- Removal of Biomass as Harvest/
  Conversion of Biomass to Residue
- Tillage / Biomixing of Soil
- Fertilizer and Manure Applications
- Edge-of-Field Buffers
- Pesticide Applications
- Irrigation
- Water Impoundment (Wetlands, Rice)
- Subsurface (Tile) Drainage

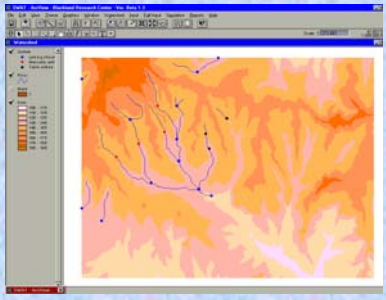
SWAT

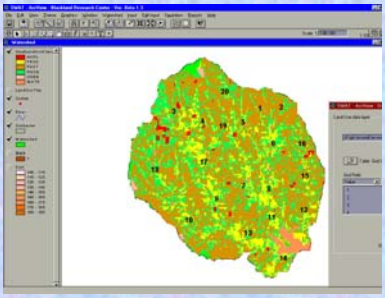
Channel Processes

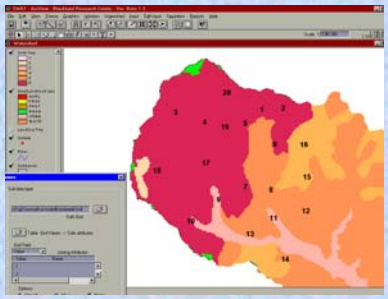
Channel Processes

- Flood Routing
- Transmission Losses, Evaporation
- Sediment Routing
  - Degradation and deposition
- Nutrients
  - modified QUAL2E
- Pesticide
  - Toxic balance

ArcView GIS Interface







Weather

- Daily Precip and Max/Min Temp
- Monthly Radiation, Windspeed, Humidity

SWAT

Calibration and Uncertainty

- Sensitivity Analysis
  - Latin Hypercube – One-factor-at-a-time
- Auto Calibration
  - Shuffled Complex Evolution Algorithm
  - Multi-Objective Optimization
- Uncertainty Analysis

SWAT

Uncertainty Analysis

- Parameter Uncertainty
  - Separate SCE optimization into "Good" and "Not Good" Sets
  - χ^2 and Bayesian Methods
- Predictive Uncertainty
  - Sources of UNcertainty GLobal Assessment using Split SamplES (SUNGLASSES)

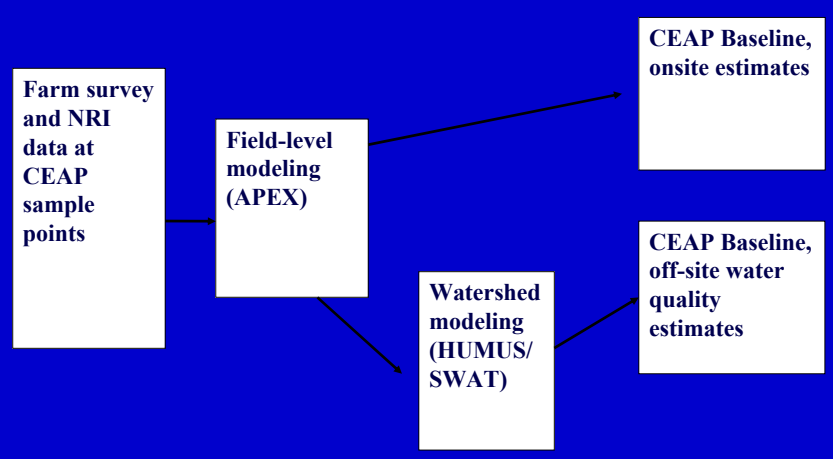
Conservation Effects Assessment Project (CEAP)

- Current Analysis
  - Grass Waterways, Contours, Terracing, Filter Strips, Buffers
- Future Analysis
  - Tillage Systems, Manure and Fertilizer Management

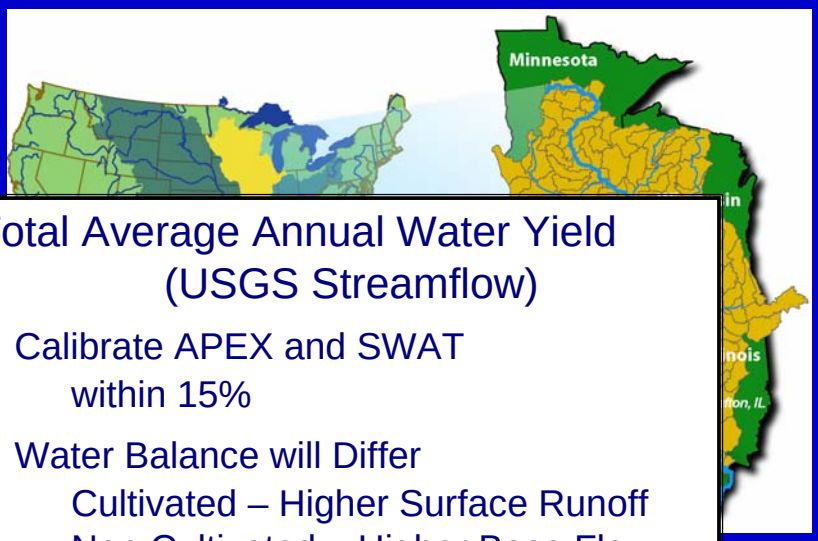
USDA ars

USDA NRCS Natural Resources Conservation Service

Schematic for Construction of CEAP Baseline

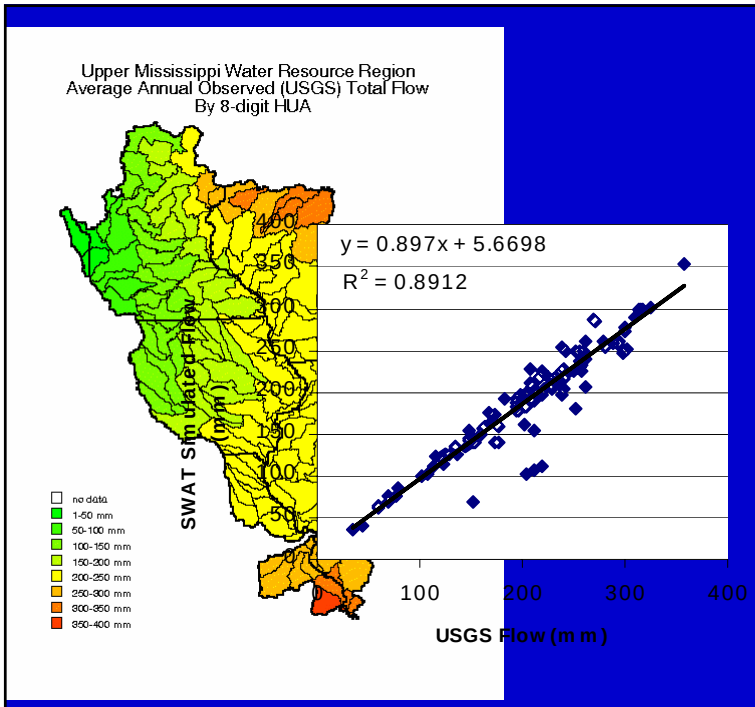


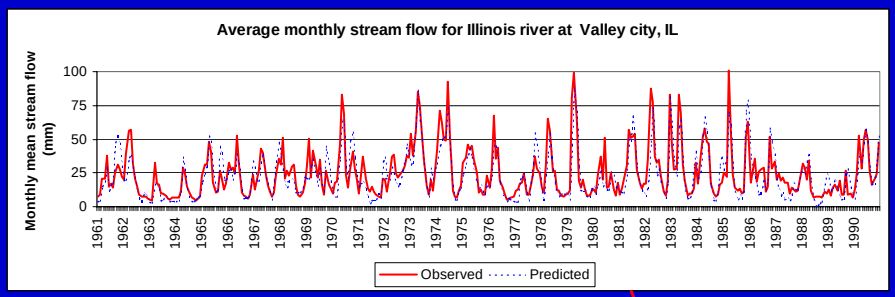
Flow Calibration Procedure

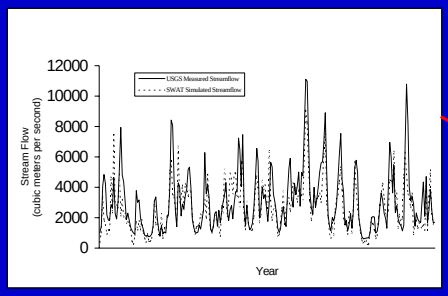


Total Average Annual Water Yield
(USGS Streamflow)

- Calibrate APEX and SWAT
  within 15%
- Water Balance will Differ
  Cultivated – Higher Surface Runoff
  Non Cultivated – Higher Base Flow

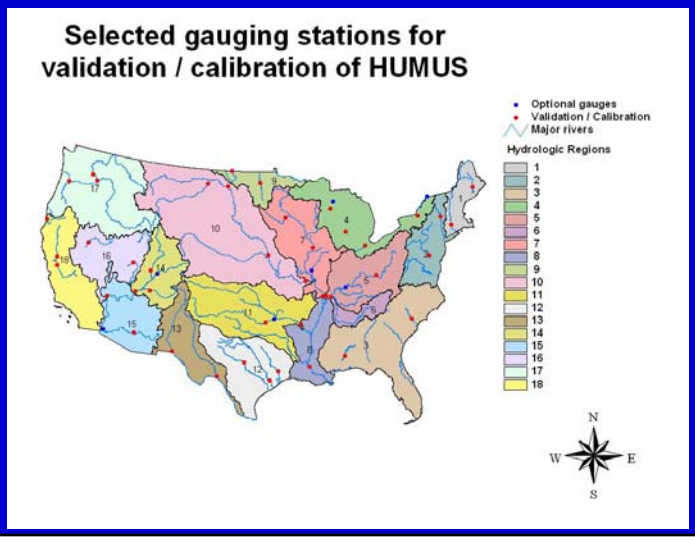


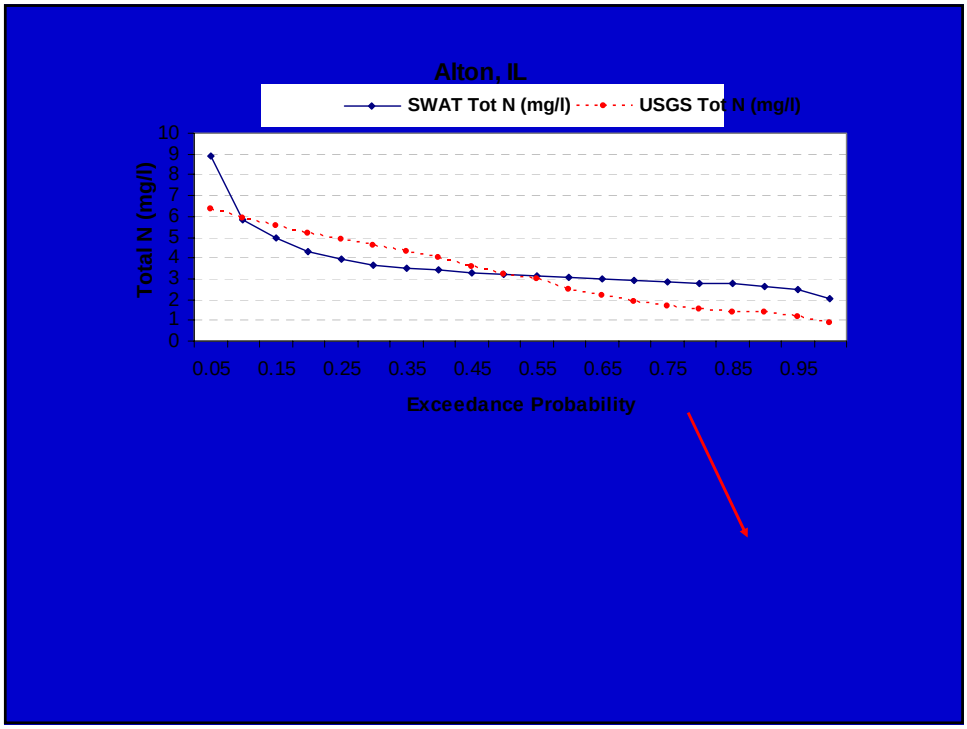




Sediment and nutrient calibration/validation

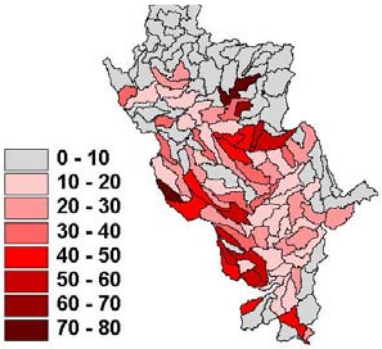
- Assembled USGS-SPARROW annual nutrient loads
- Sediment and nutrient data at USGS-Gages



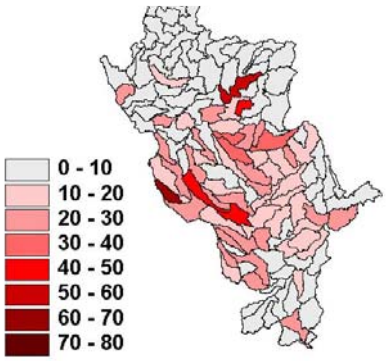


Percent Reduction in Sediment Loading by HUC

Agland (APEX) Only

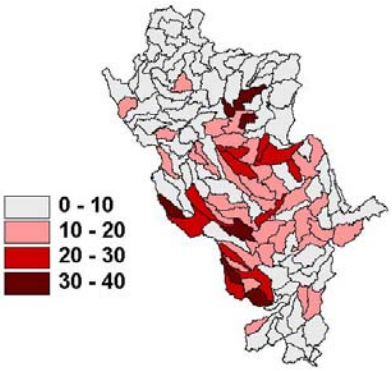


All Sources
(Ag, Non-Ag, Point Sources)



Percent Reduction in Total Nitrogen Loading by HUC

Agland (APEX) Only



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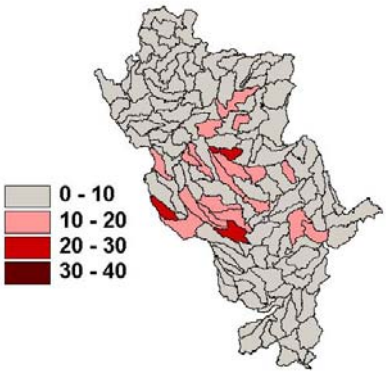
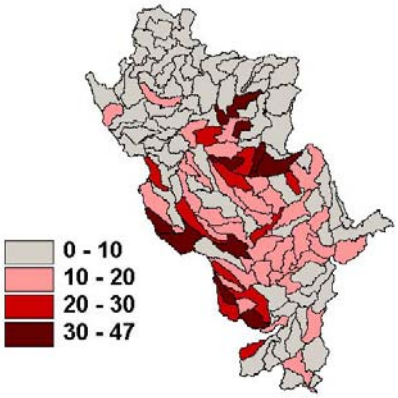
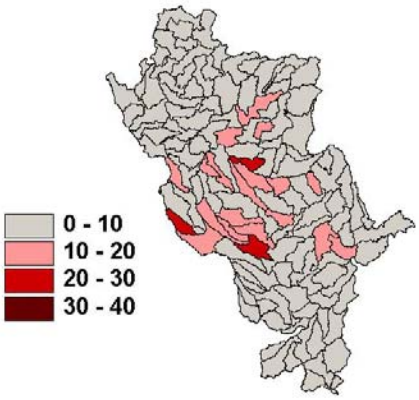


Percent Reduction in Total Phosphorus Loading by HUC

Agland (APEX) Only



All Sources
(Ag, Non-Ag, Point Sources)

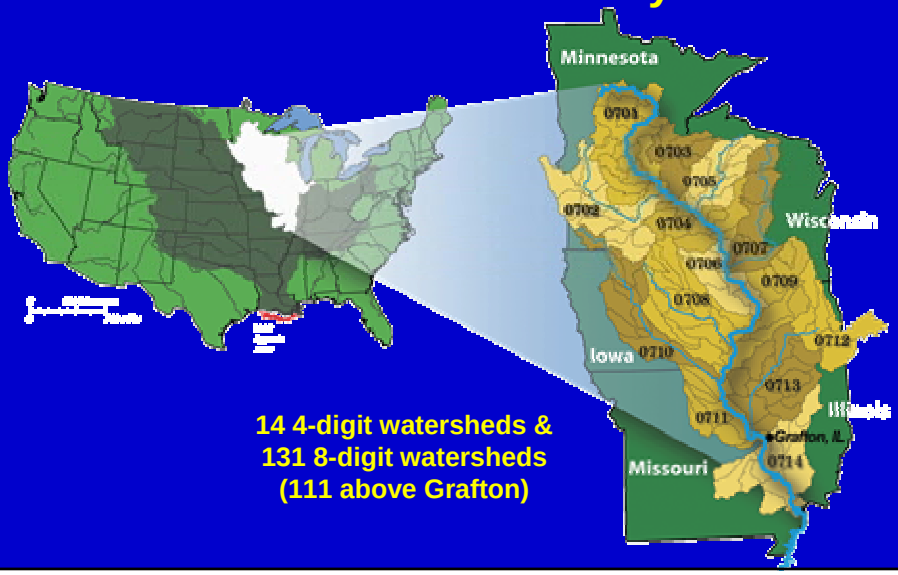


Preliminary Results
Grafton, IL

- Sediment Reduction
  820,000 tons/yr 4.2%
- Total Nitrogen
  11,036 tons/yr 5.1%
- Total Phosphorus
  2,351 tons/yr 4.8%

n Results

Center for Agricultural and Rural Development (CARD) Iowa State University



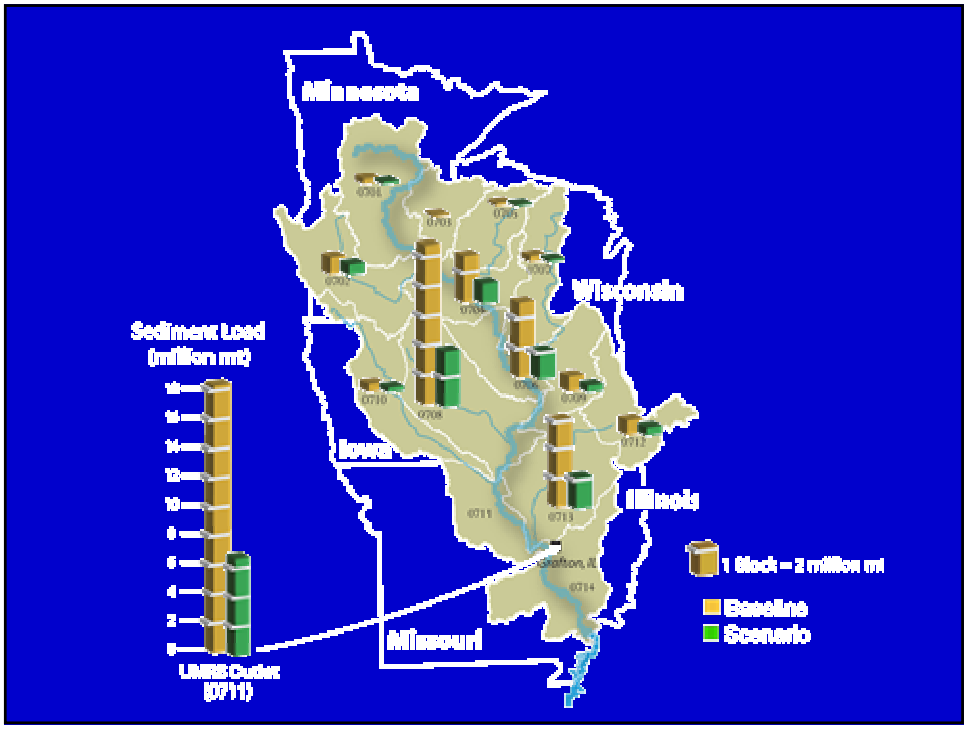
14 4-digit watersheds &
131 8-digit watersheds
(111 above Grafton)

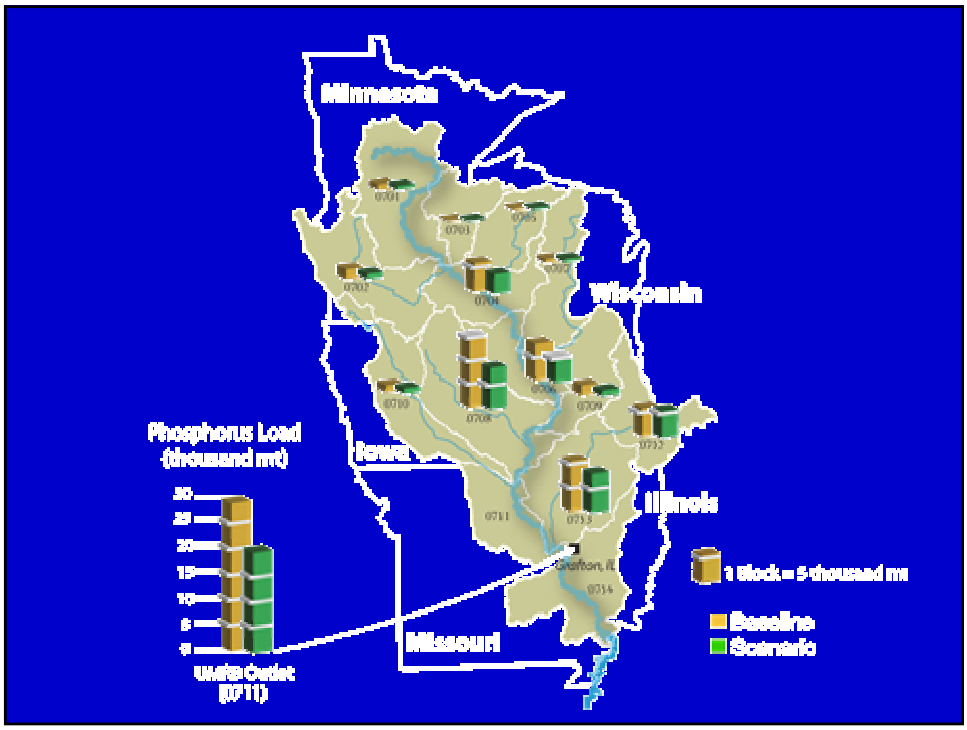
Key Model Components

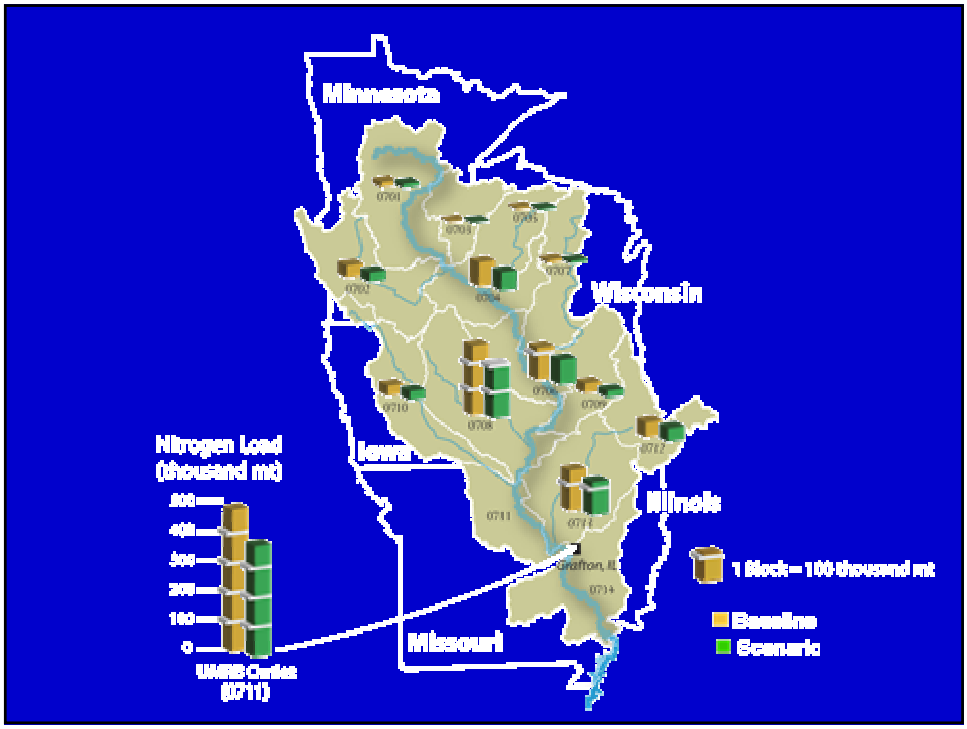
- SWAT model – configured with 8-digit subwatersheds & HRUs
- 1997 USDA NRI database – 114,000 UMRB points representing baseline land use, conservation practices, etc.
- Other tillage, fertilizer, climate, & soil data

Conservation Practices

- Retire Land
- Terracing and Contouring
- Grassed Waterways
- Conservation Tillage


Minnesota
Wisconsin
Iowa
Illinois
Missouri
Sediment Load
(million mt)
UMRB Outlet
(0711)
1 block = 2 million mt
Baseline
Scenario


Minnesota
Wisconsin
Iowa
Illinois
Missouri
Phosphorus Load
(thousand mt)
UMRB Outlet
(0711)
1 block = 5 thousand mt
Baseline
Scenario



SWAT

Future Development

- Potholes – Surface Tile Inlets
- Tile Flow – Drainmod Equations and Controlled Drainage
- Landscape Processes
- Pathogens – Bacteria Source Tracking
- Sediment and In-Stream Routing
- Databases