Lessons From Agricultural Ditches – Modeling and Management of Agricultural Drainage

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Background

- Agricultural drainage is vital to crop production in many areas where soils are poorly drained
  - Increased depth of aeration, warmer soil temps, improved trafficability, etc
  - Much of the CBW utilize ditch networks for drainage
- Ag drainage management has historically focused on shedding water as fast as possible and not on management of drainage for environmental benefits

Motivation

- Most of our drainage management tools are focused on Tile Drained systems (e.g., Drianmod)
  - Little work has sought to develop predictive or assessment tools aimed at ditch systems
  - As a result, we have sometimes dogmatically* developed control practices based on what works in other systems and not on prudent management of ditch drained systems

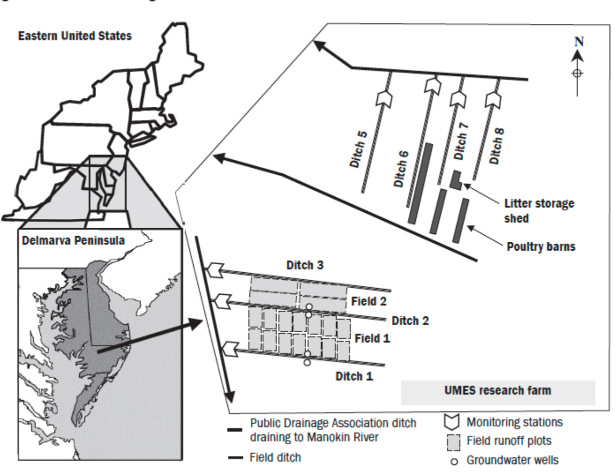
***dog·ma** …, *n.* … **2.** a specific tenet of doctrine authoritatively put forth: *the dogma of the Assumption.* -The Random House Dictionary

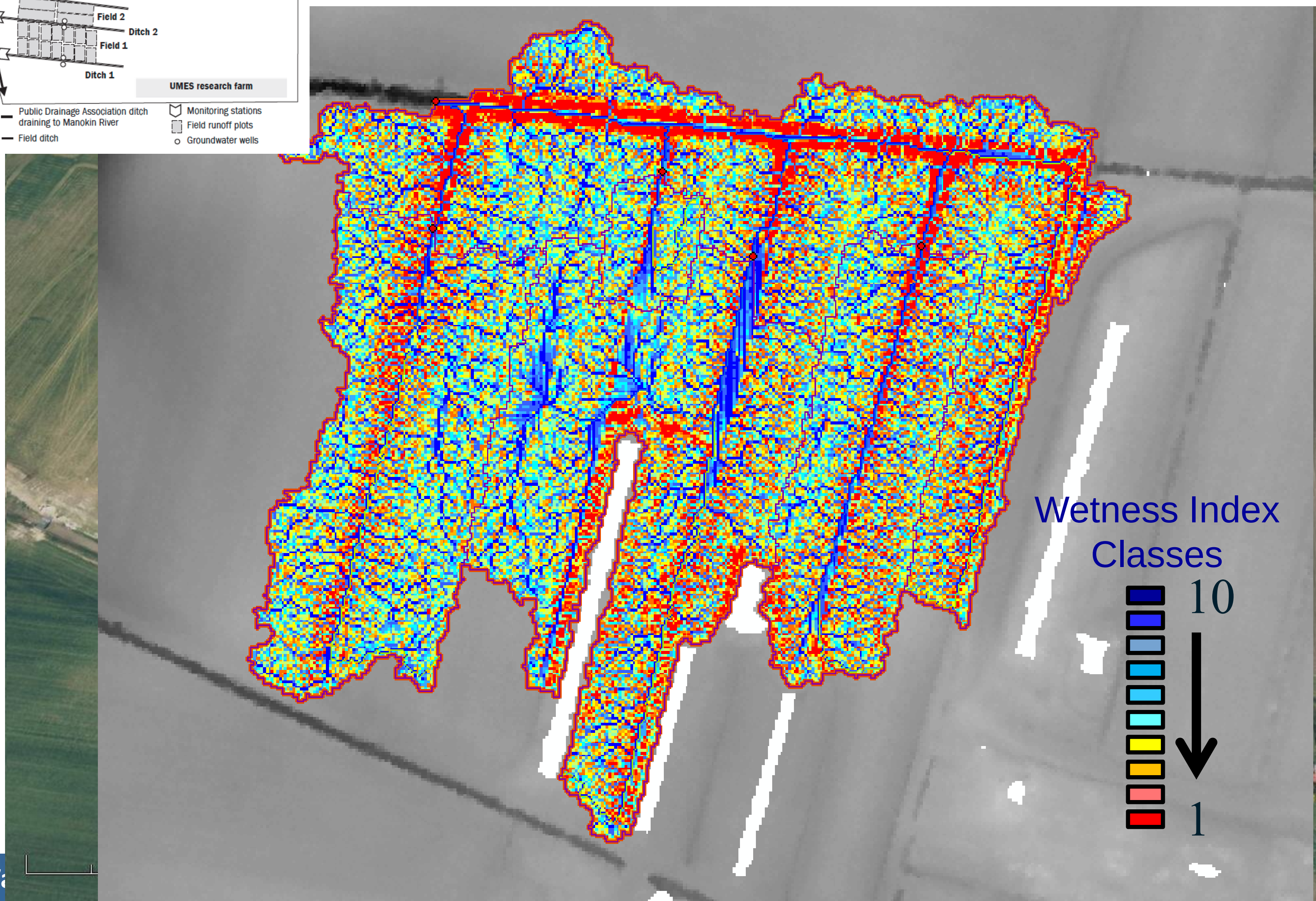
Outline

- Model 1: A Watershed Model We Trick Into Working in Ditched Systems
- Model 2: A Ditch Indexing Method
- Management of Agricultural Ditches

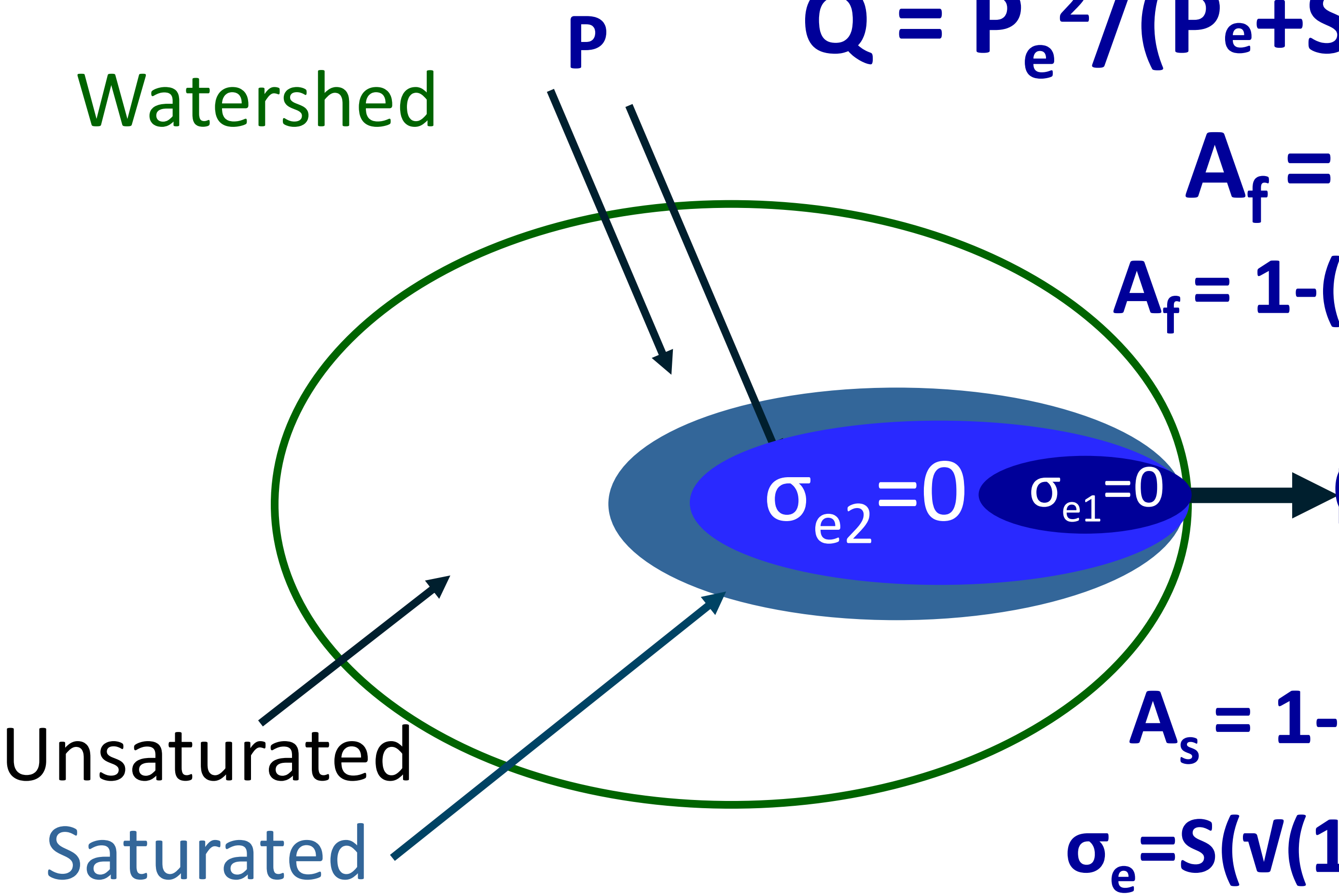
Model 1.

Manokin River watershed, Princess Anne MD
SWAT-VSA





Runoff Analysis



(streamflow or "excess" water)

$$Q = P_e^2/(P_e+S)$$

$$A_f = \partial Q/\partial P_e$$

$$A_f = 1-(S^2/(P_e+S)^2$$

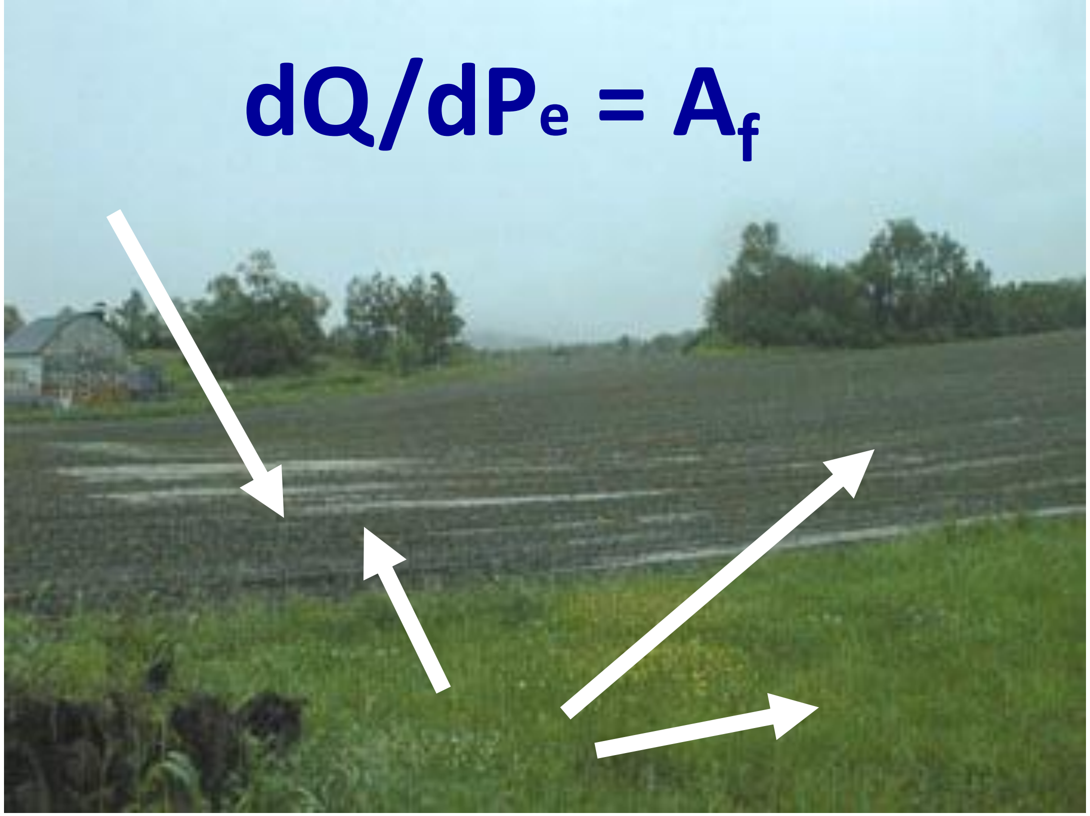
$$A_s = 1-(S^2/(\sigma_e+S)^2$$

$$\sigma_e=S(\sqrt{(1/(1-A_s))}-1$$

$$A_f,\ A_s,\ \sigma_e = f(S,P_e)$$

Easton et al., 2008. *J. Hydrol*
Easton et al. 2011. Hydrol Proc

We know how much area is contributing and the volume of runoff…

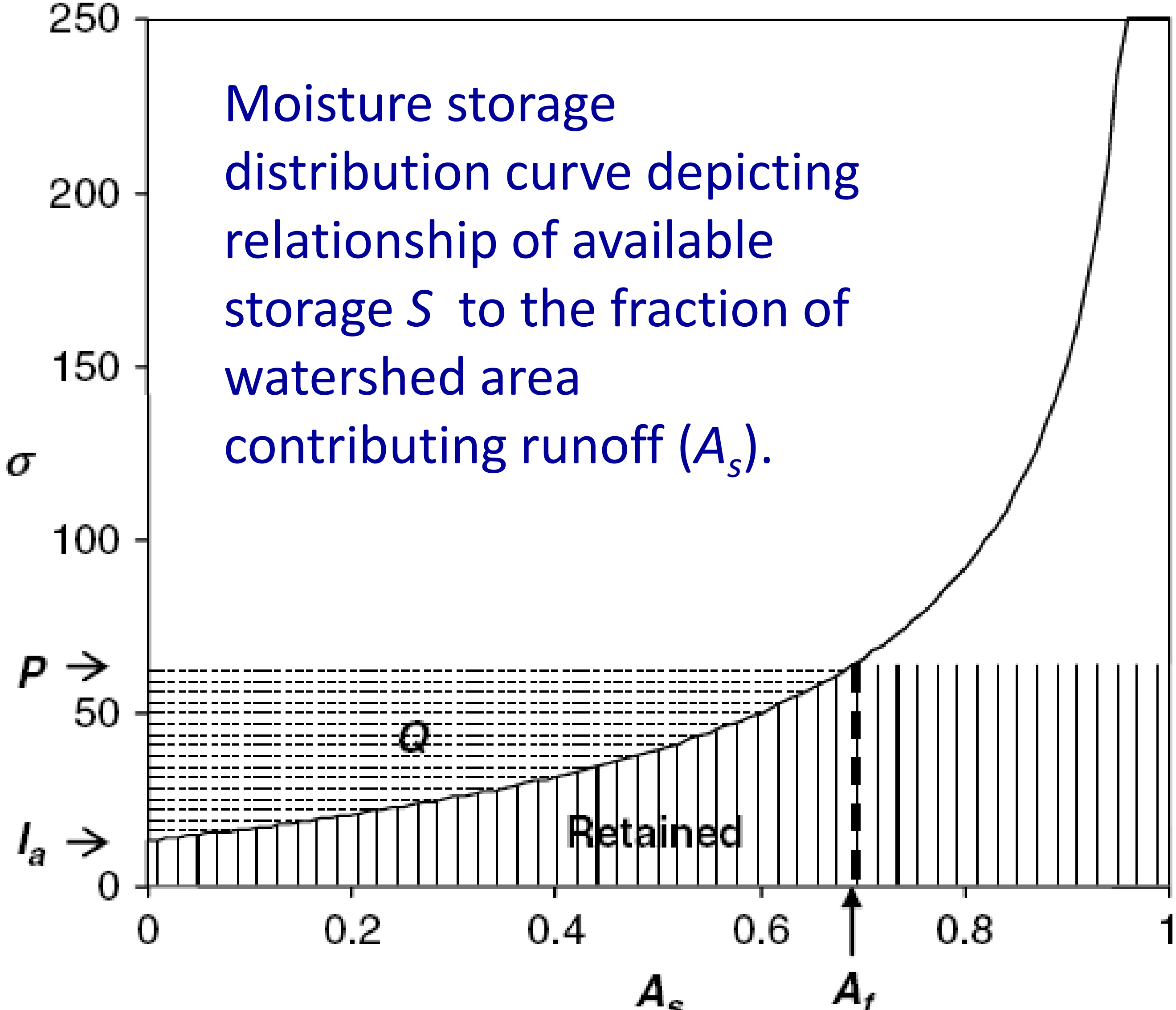


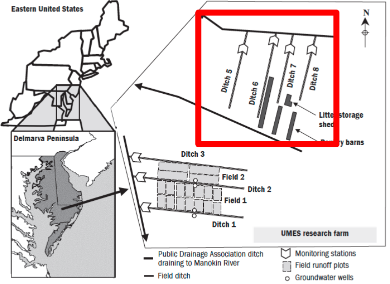
…but from where in the landscape?

Distributing Runoff

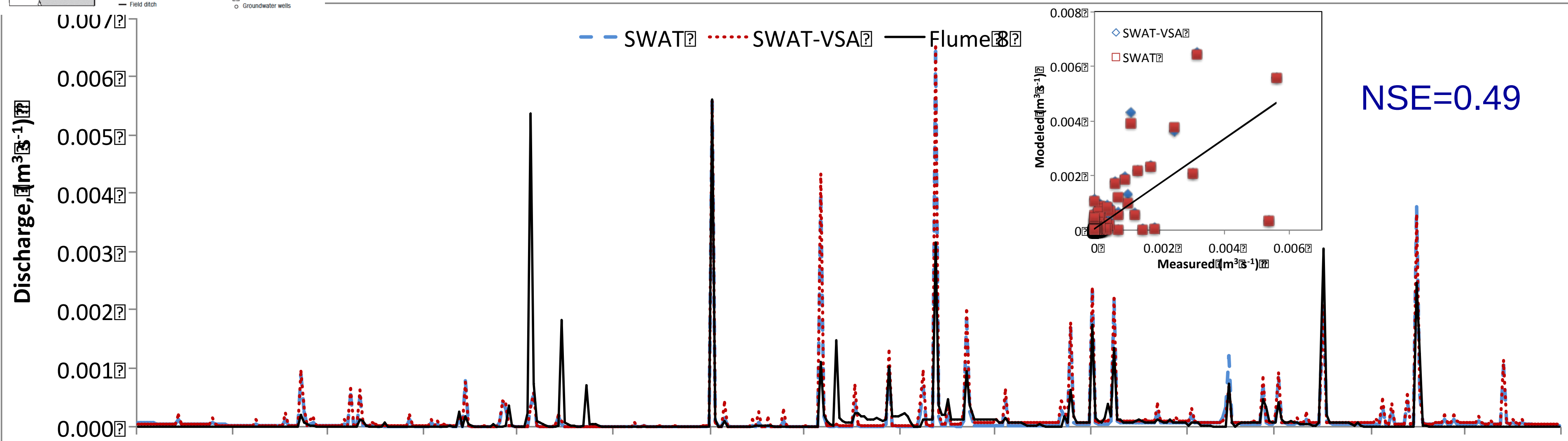
$$\lambda = \ln\left(\frac{a}{T\tan\beta}\right)$$

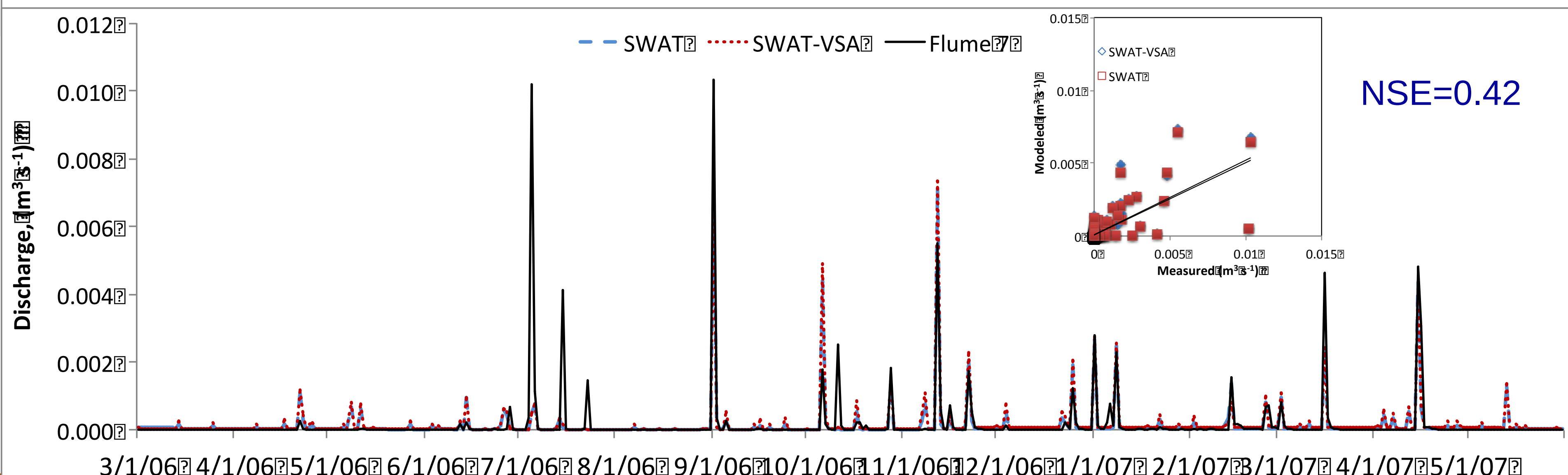
Moisture storage distribution curve depicting relationship of available storage *S* to the fraction of watershed area contributing runoff (A_s).



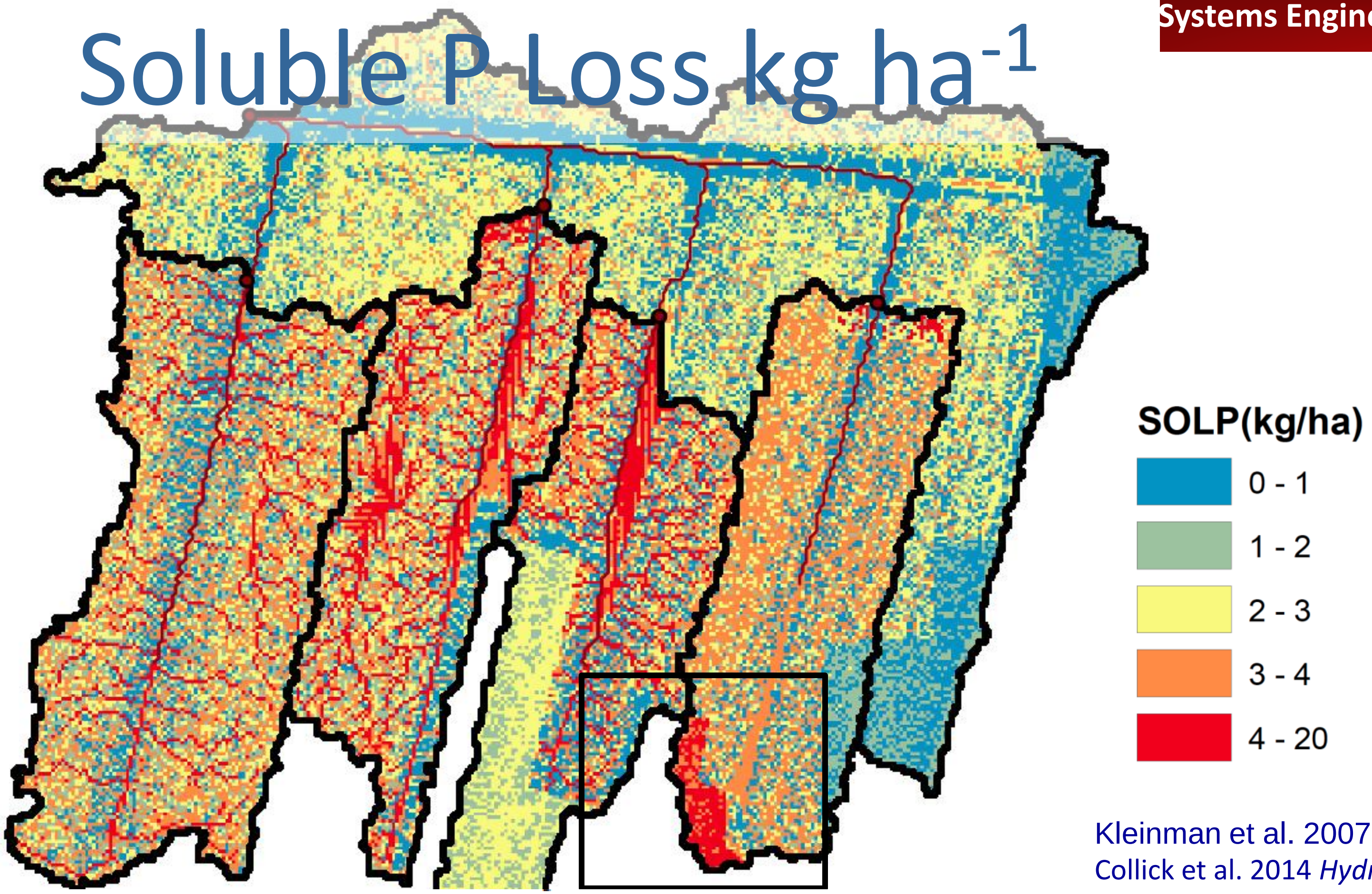


Ditches 7 and 8





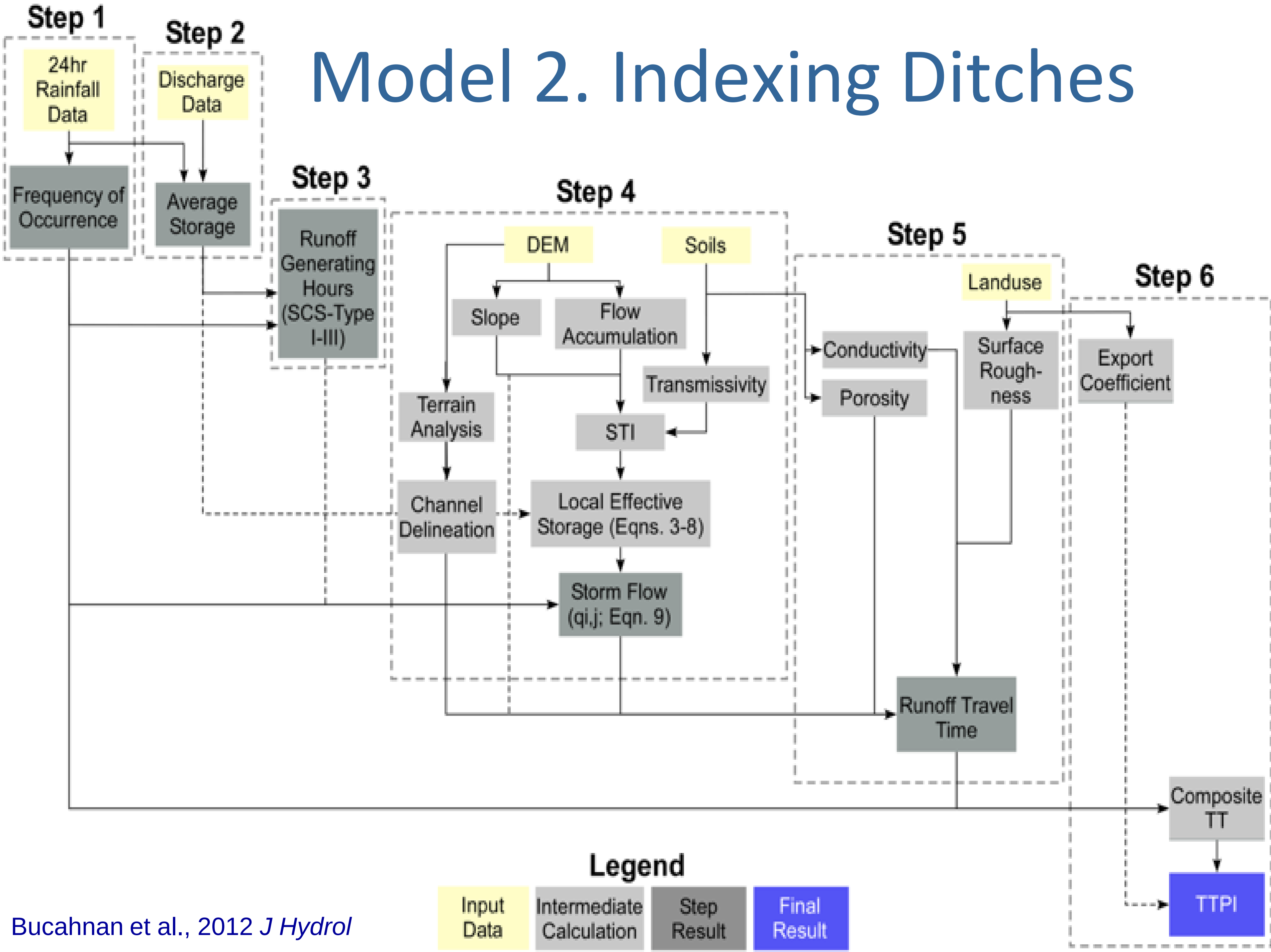
Soluble P Loss kg ha^{-1}



Kleinman et al. 2007 *JSWC*
Collick et al. 2014 *Hydrol Proc*

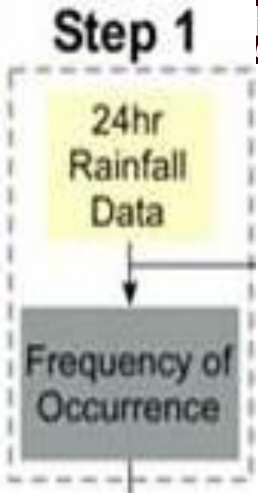
Ditch	Flow (m^3)	Concentrations* DRP (mg L^{-1})	Concentrations* TP (mg L^{-1})	Concentrations* Total solids (g L^{-1})	Loads DRP (kg)	Loads TP (kg)	Loads Total solids (Mg)	Losses† DRP (kg ha^{-1})	Losses† TP (kg ha^{-1})	Losses† Total solids (Mg ha^{-1})
1	6,163	0.25 (0.13)	1.02 (0.74)	0.39 (0.18)	1.6	7.3	2.4	0.6	2.7	0.9
2	11,556	0.31 (0.27)	0.51 (0.47)	0.47 (0.28)	4.4	5.9	5.5	2.5	3.3	3.1
3	12,827	0.56 (0.43)	0.75 (0.46)	0.35 (0.22)	7.9	9.7	4.5	3.6	4.8	2.3
5	3,174	0.90 (0.26)	0.90 (0.52)	0.31 (0.20)	2.9	2.9	1.0	2.6	2.6	0.9
6	1,414	2.02 (1.45)	3.20 (1.57)	0.20 (0.07)	3.3	4.5	0.3	3.2	4.3	0.3
7	3,450	2.22 (1.44)	3.01 (1.39)	0.10 (0.06)	7.7	10.4	0.8	6.4	8.6	0.7
8	3,382	4.05 (1.75)	6.17 (2.05)	0.34 (0.07)	13.7	20.9	1.1	16.6	25.3	1.4

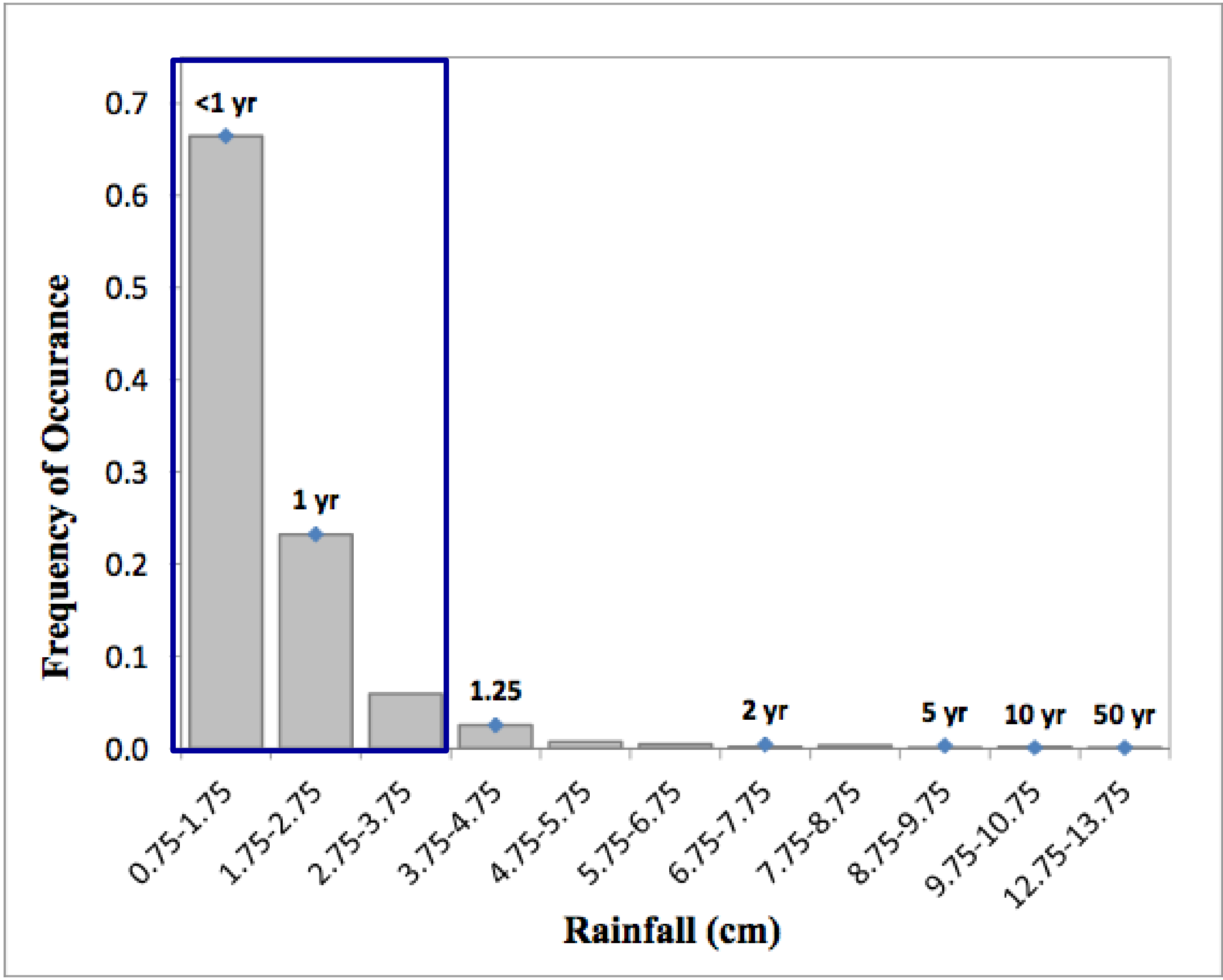
Model 2. Indexing Ditches



Bucahnan et al., 2012 *J Hydrol*

Rainfall Analysis

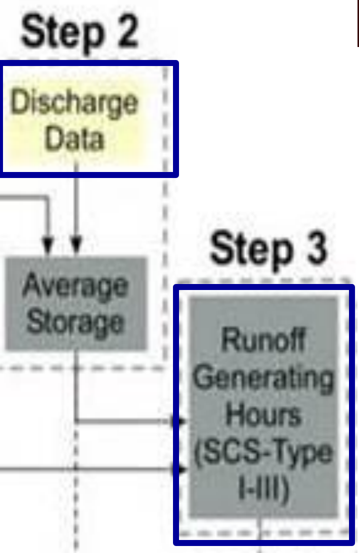




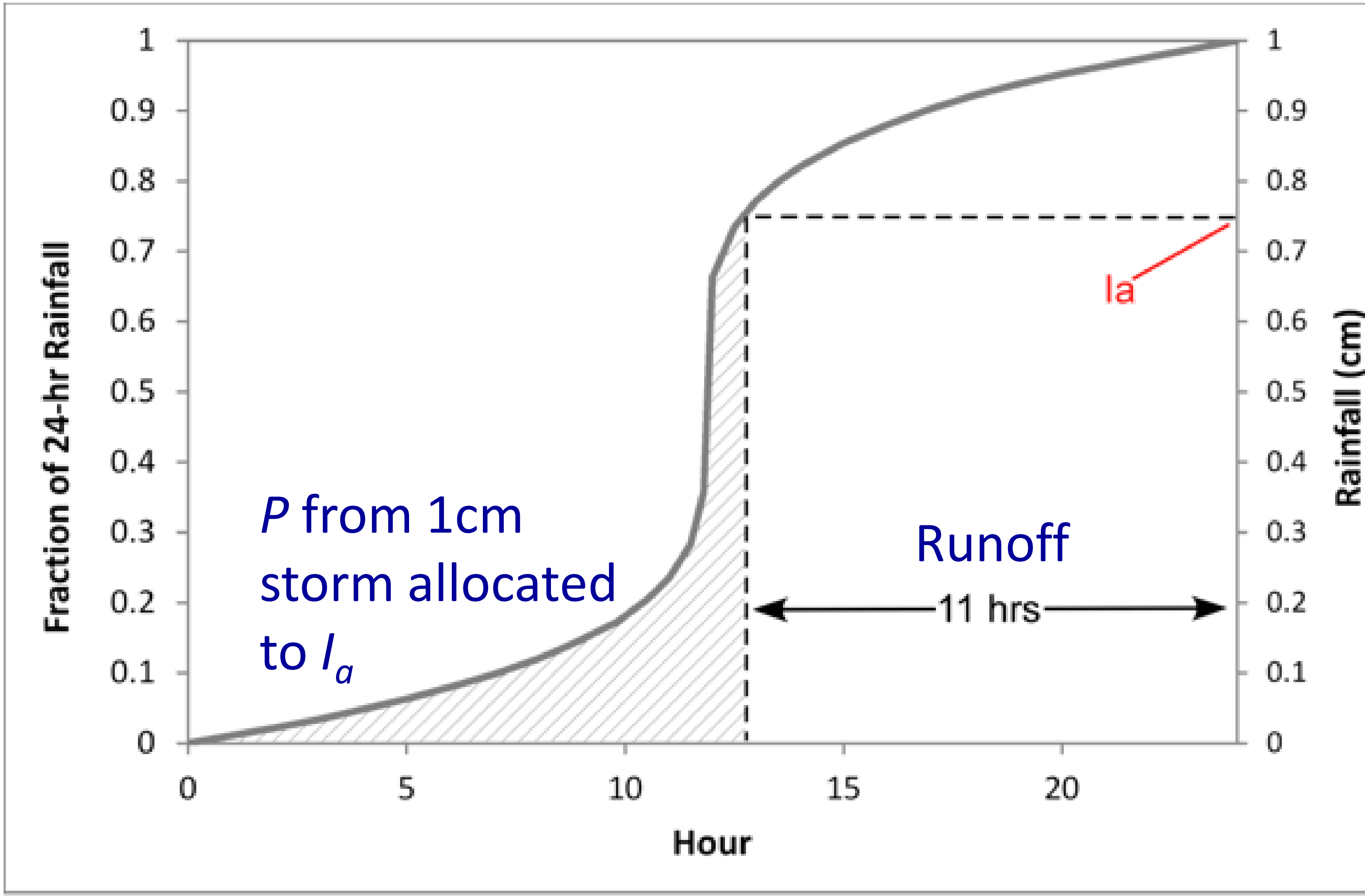
$$f_i = m_i/N$$

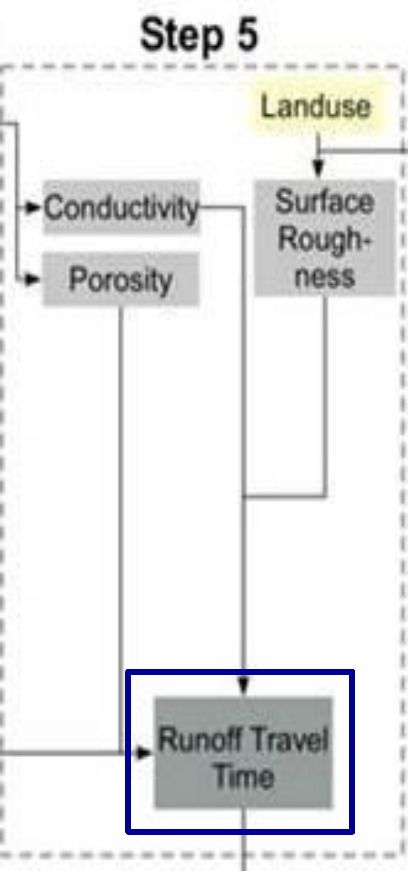
f_i is the frequency of occurrence

m_i is the bin, N total rainfall events



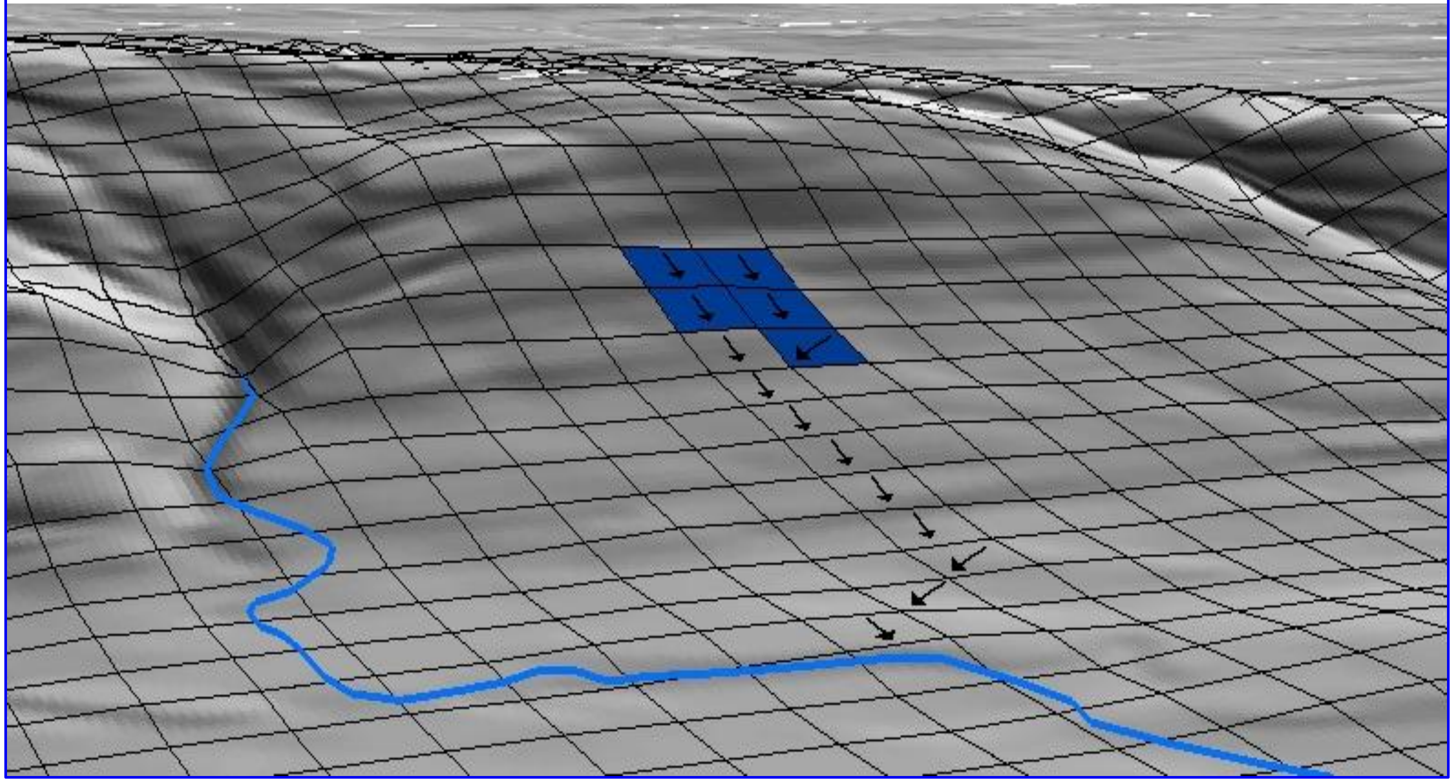
In the CN equation $Q = P_e^2 / (P_e + S)^2$ we use paired rainfall (P_e) runoff (Q) data to solve for storage (S)



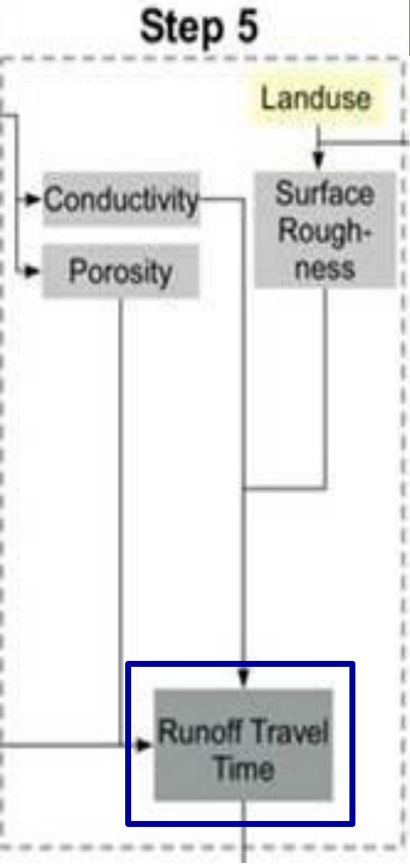


Travel Times

Multi Directional (d-infinity) Routing



Three Phase Travel Time (i) **storm runoff**, (ii) **shallow interflow**, iii) **ditches**



i) Surface Runoff: Steady state kinematic wave approximation with Manning's equation

$$TT_R = q_{t,i,k}^{-0.4} \left(\frac{L^{0.6}\, n^{0.6}}{\beta^{0.3}} \right)$$

ii) Interflow: Steady state flow through soil

$$TT_I = \frac{L}{\left(\frac{K_{Lat}}{n_e} \beta \right)}$$

ii) Ditches: Manning's equation and the continuity equation

$$TT_D = \frac{L}{\left(\frac{\beta^{0.5}}{n} \left(\frac{Q}{W} \right)^{0.67} \right)^{0.6}}$$

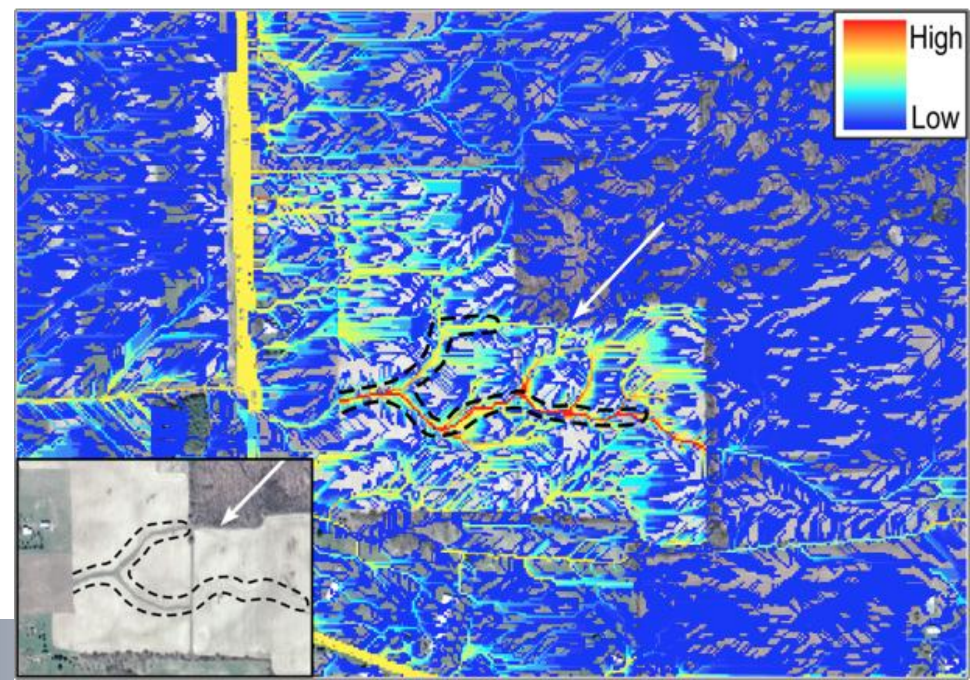
The cumulative travel times (C_{TT}) to streams are the sum of each grid cell travel time along each flowpath

Indexing Approach

Landuse	P kg/ha/yr
Forest	0.06
Pasture	0.49
Corn/Soybean	0.67
Manured Cornfield	3.05
Barnyard	3.05
Ditch	0.49

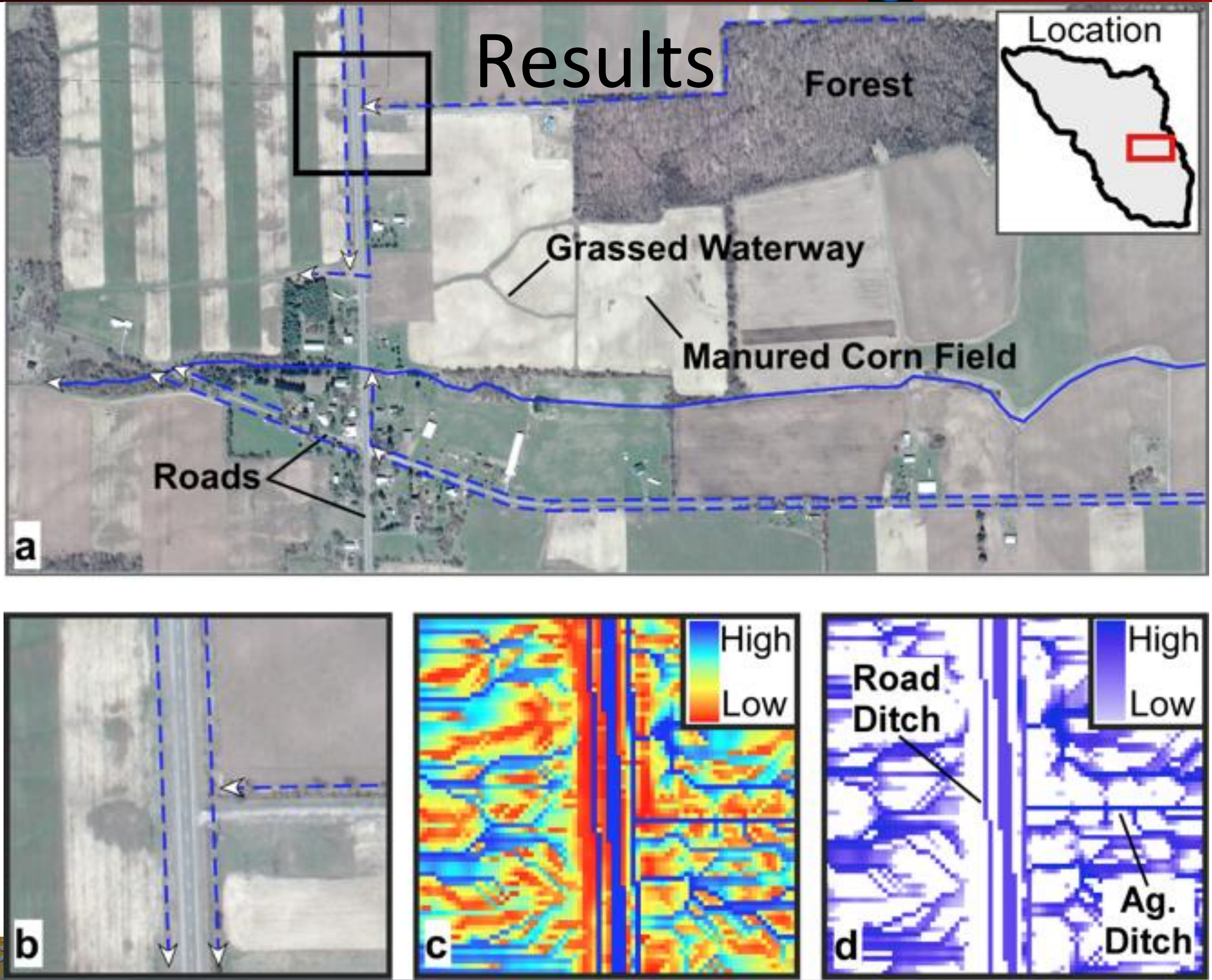
X

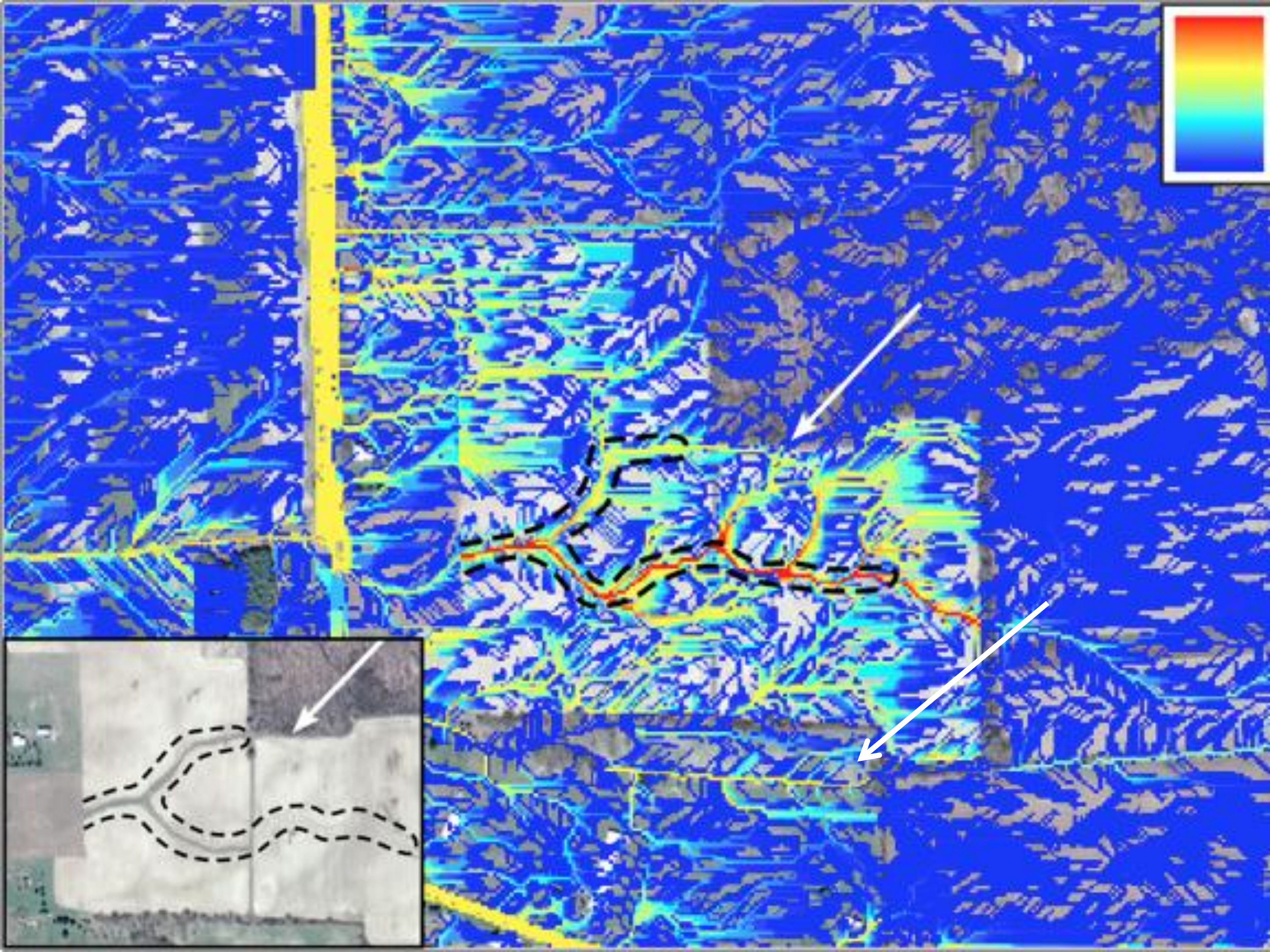
$$C_{TT} = \left(\sum_{i=1}^{M} \frac{f_i}{TT_{R,I,D}} \right)$$

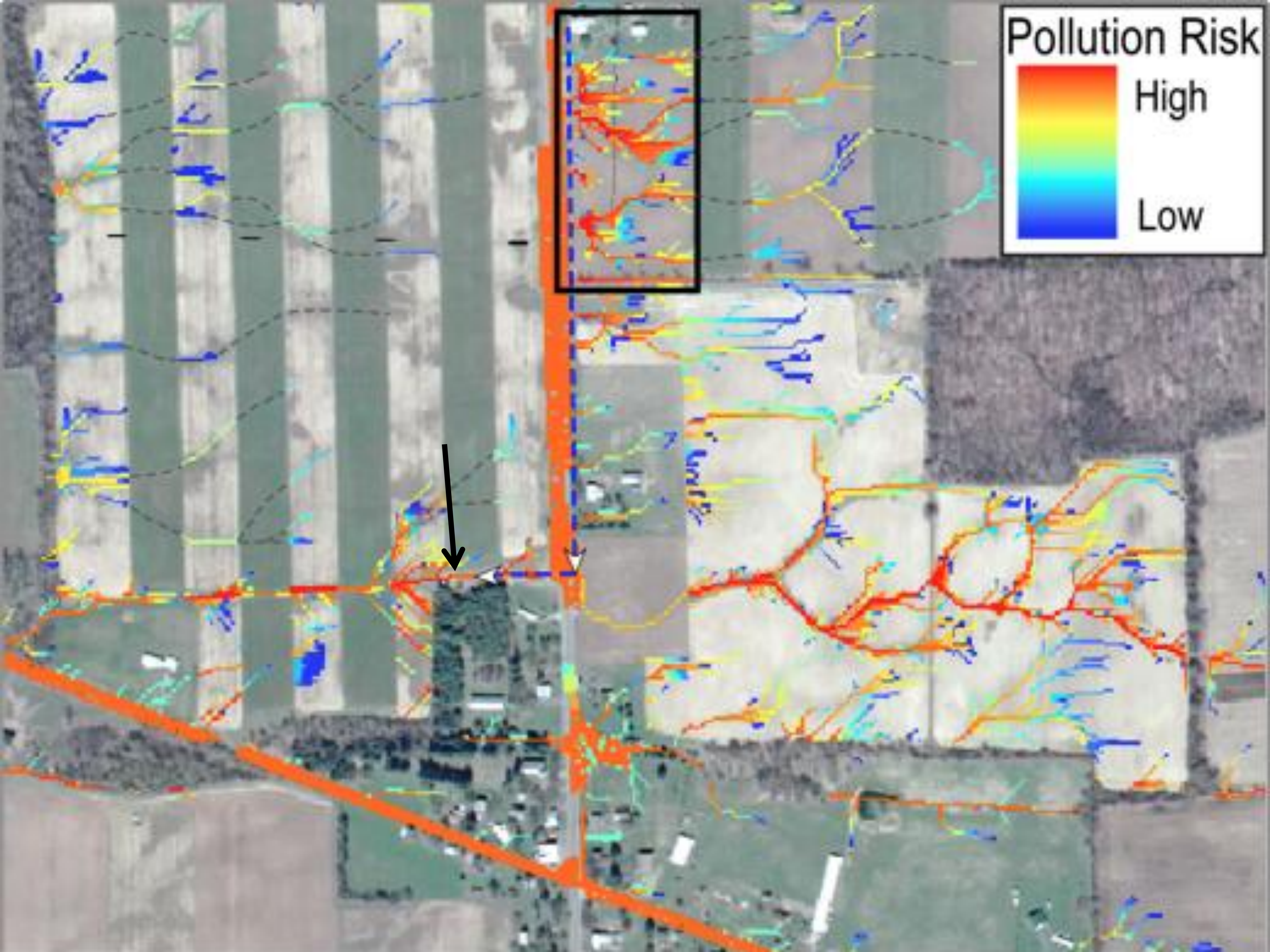


Model 2.

Results

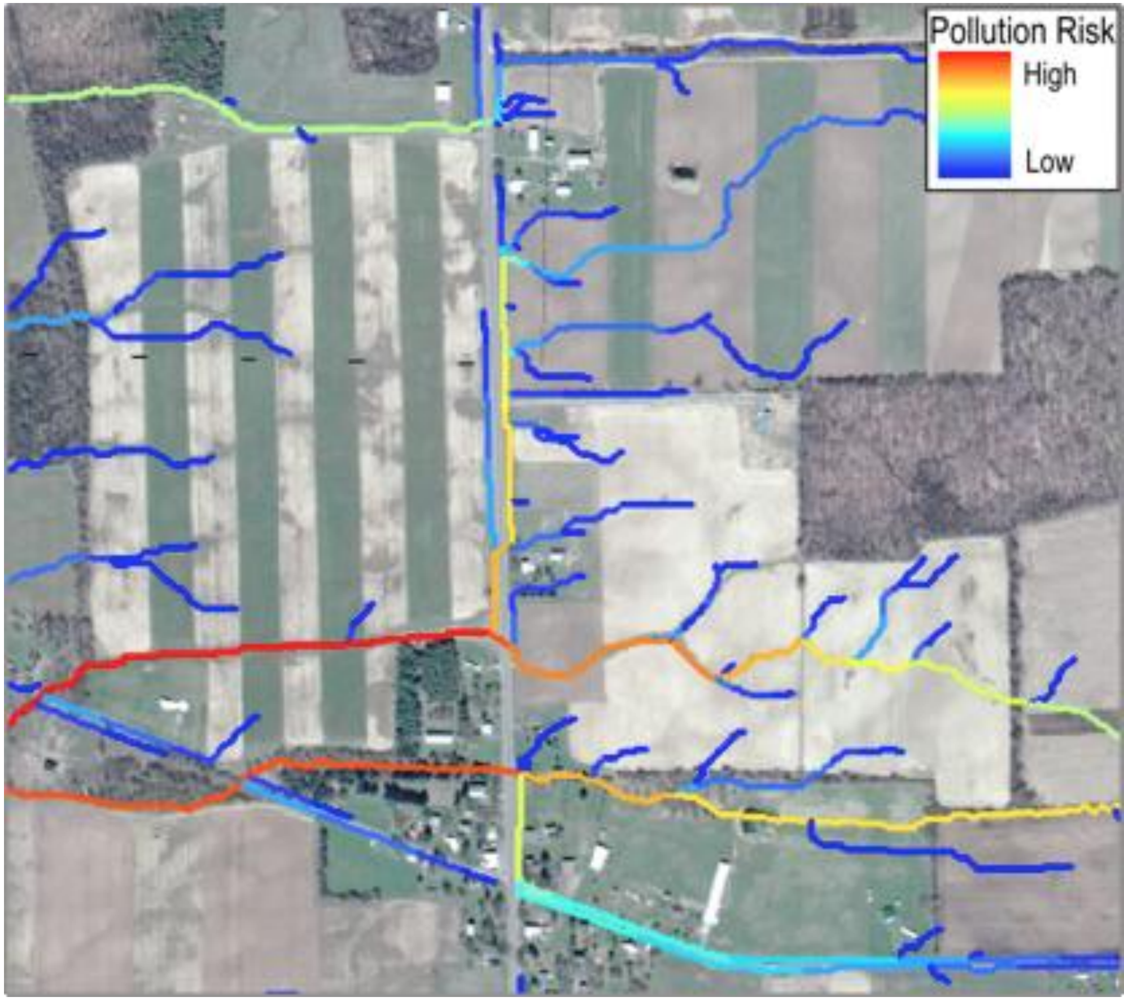





Pollution Risk
High
Low

Channels

- Which hydrologic pathways are of concern from a pollution risk standpoint
- Which channels are good candidates for transport-specific conservation measures

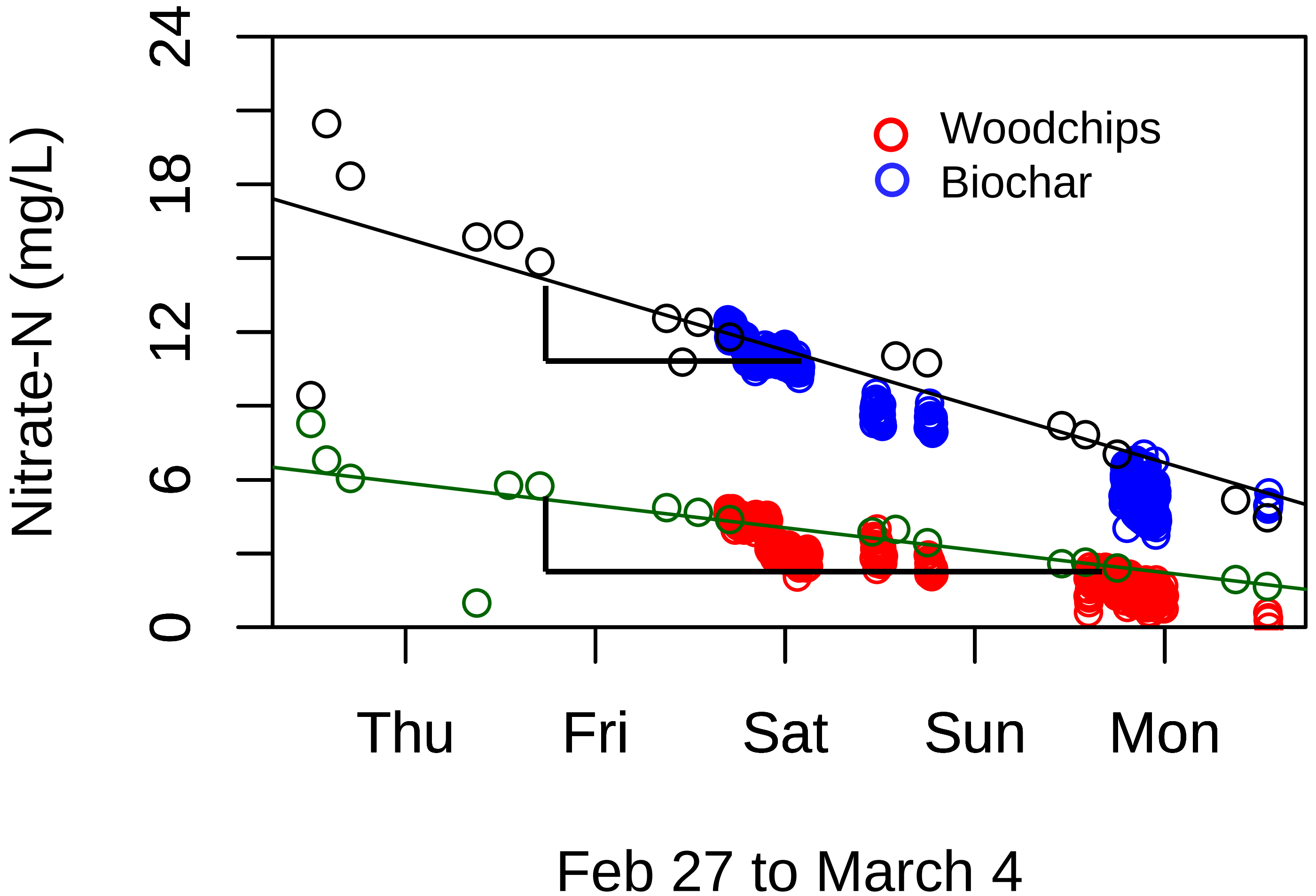


Management

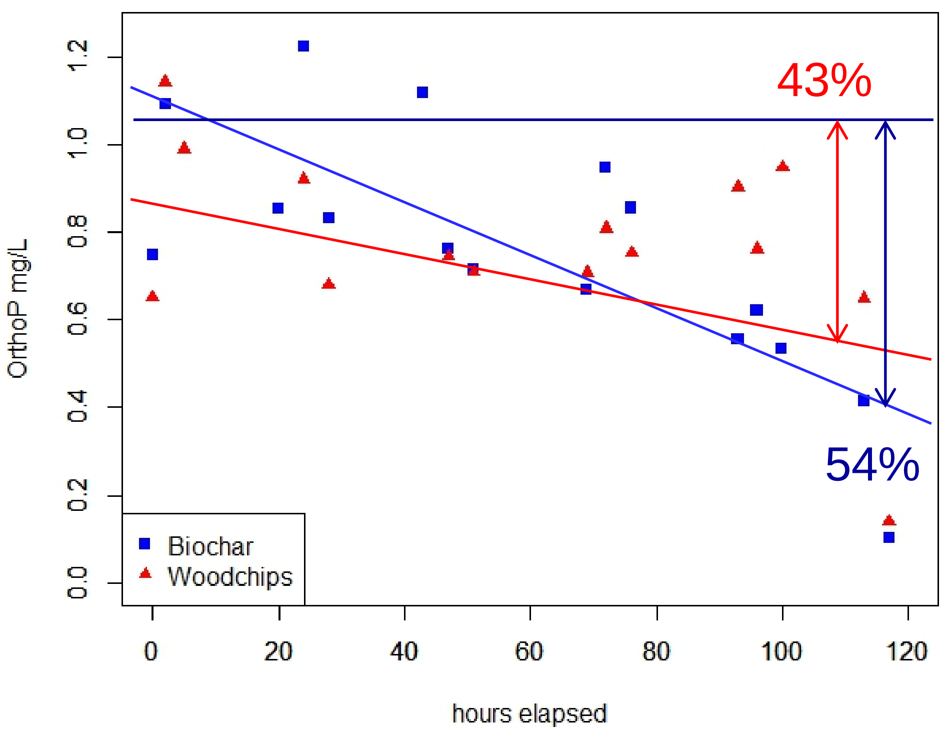
- Drainage/flow control structures
  - Reduce peak flows in ditches
  - Increase the contact with biologically, physically and chemically active surfaces
  - Promote denitrification by increasing the anaerobic period
- Modify conventional ditch management practices
  - Substitute mowing for mechanical scraping or reduce frequency
    - Contact with biologically, physically and chemically active surfaces
    - Reduced erosion and better bank stability >> less maintenance

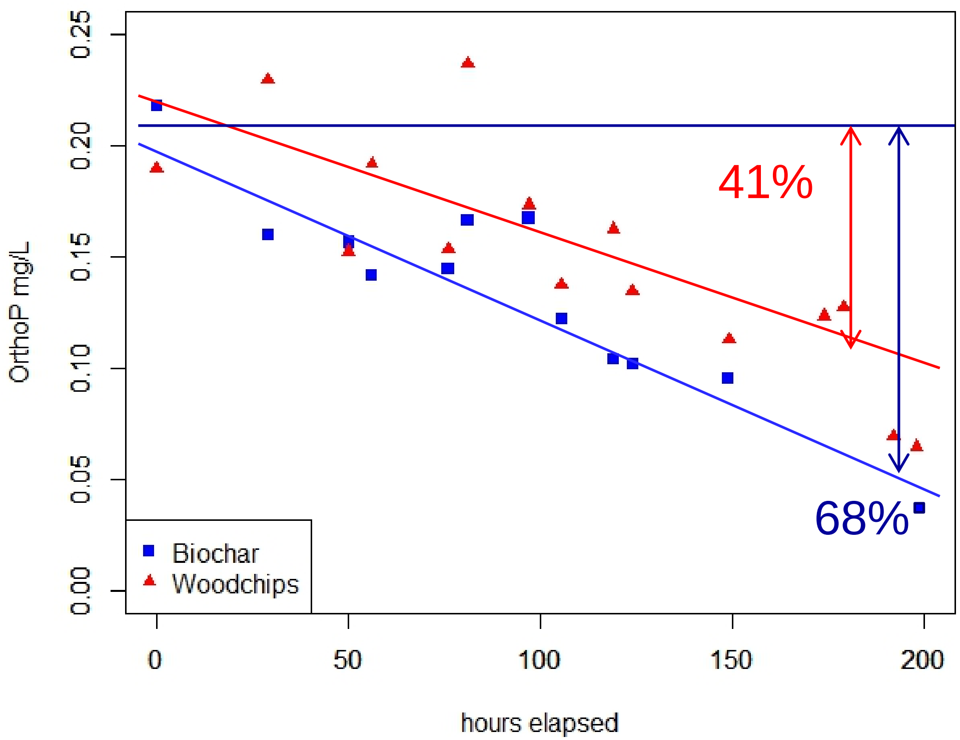
Management

- Ditch Filtration
  - In-ditch biofilter
    - Big hole
      - Filled with carbon
      - Intercepts ditch flow, reduces N and P


Nitrate-N (mg/L)
0
6
12
18
24
Woodchips
Biochar
Thu
Fri
Sat
Sun
Mon
Feb 27 to March 4

Phosphate





Lassiter et al. 2014 *JEMA* (In Review)
Bock et al. 2014 *JEQ*

Conclusions

- "Corridor" role of Ag ditch network
  - Ditches can drain a significant fraction of watershed area, increasing drainage density, and decreasing flow distance to channels
- Models are *helpful* to identify which channels are good candidates for transport-specific conservation measures
  - Accurate representation of basin hydrography, including fine-scale artificial drainages, is critical to the accurate simulation of hydrologic response
  - Important to consider whole system, ditch and contributing area
- Ditch management and In-Ditch Biofilters can reduce N and P export from ditch drained systems

Ditch Humor…Sorry