United States Department of Interior

USGS

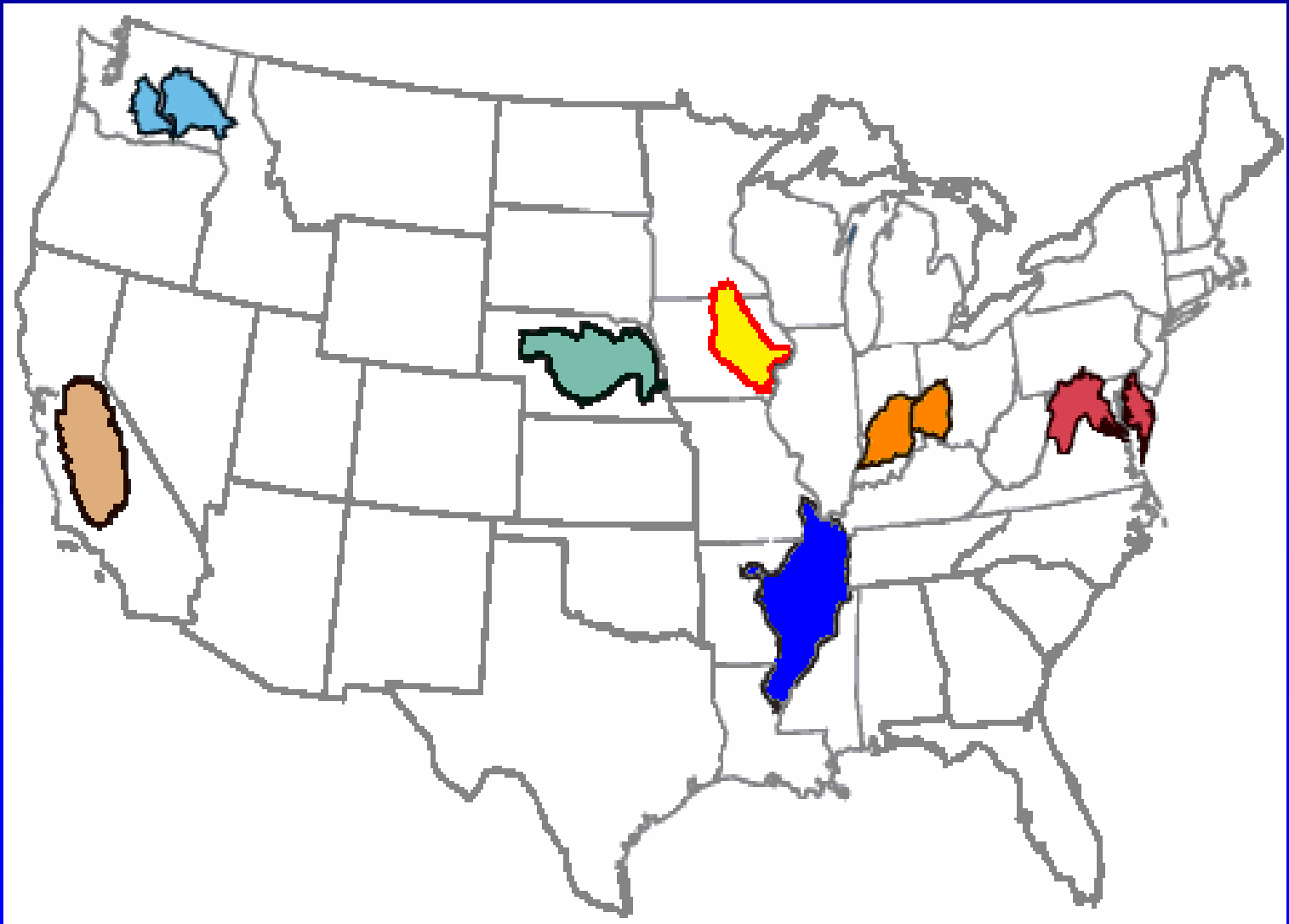
science for a changing world

National, Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

Paul D. Capel and Jeffrey W. Frey

September 18, 2006

Agricultural Chemicals: Sources Transport and Fate (ACT) Study - Locations



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Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

OVERALL QUESTION

How do environmental processes and agricultural practices interact to affect the transport and fate of agricultural chemicals in the hydrologic system of nationally important agricultural settings, and what are the effects on water quality and implications for management of water resources?

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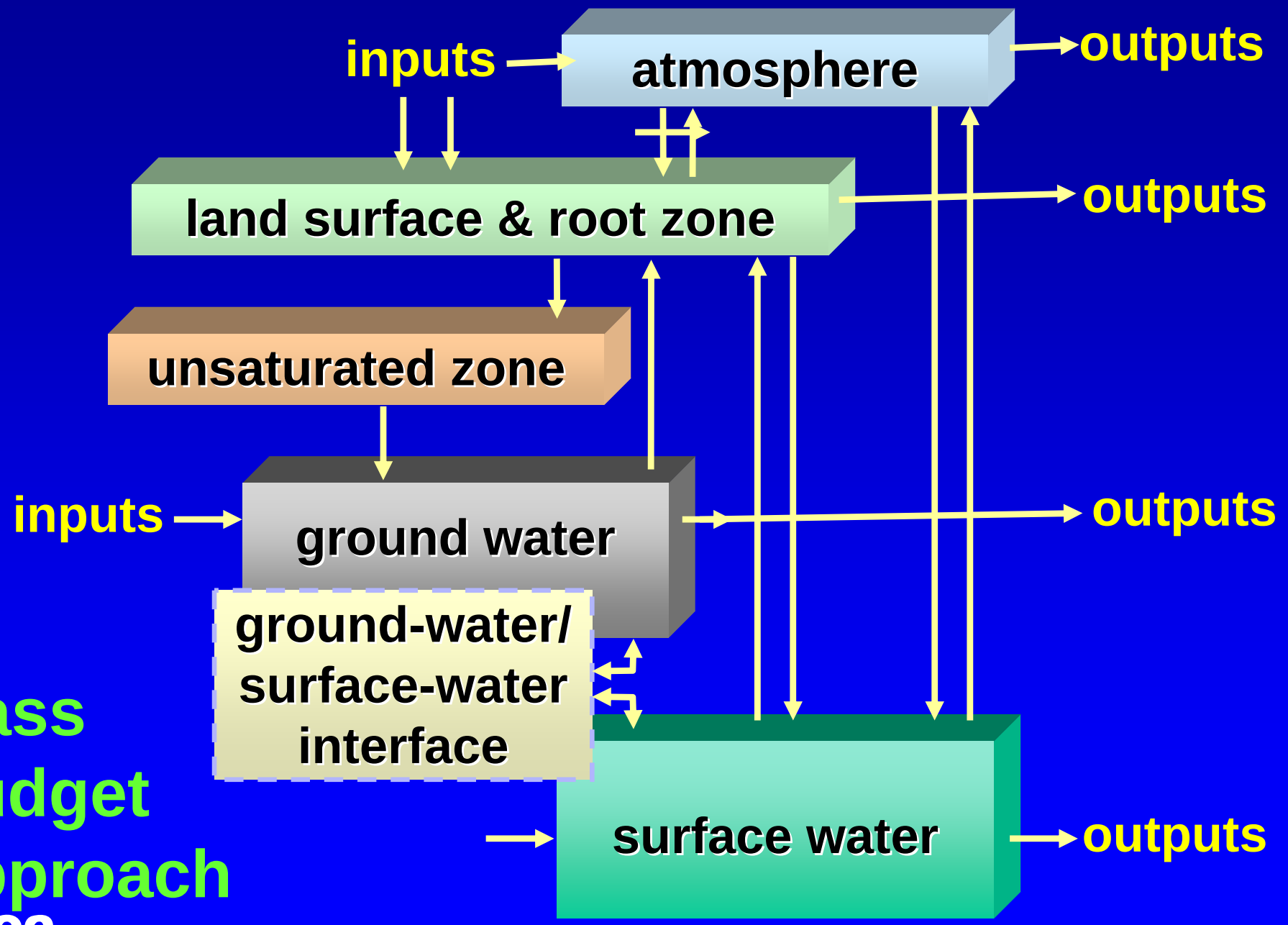

Mass Budget Approach

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Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

SPECIFIC OBJECTIVES

5. Interpret results as to the implications for managing the water and water-quality impacts

1. Develop mass budgets

2. Determine residence times and rates of transport.

4. Use quantitative methods for interpretation, extrapolation, and prediction

3. Identify the important transformation and transfer processes

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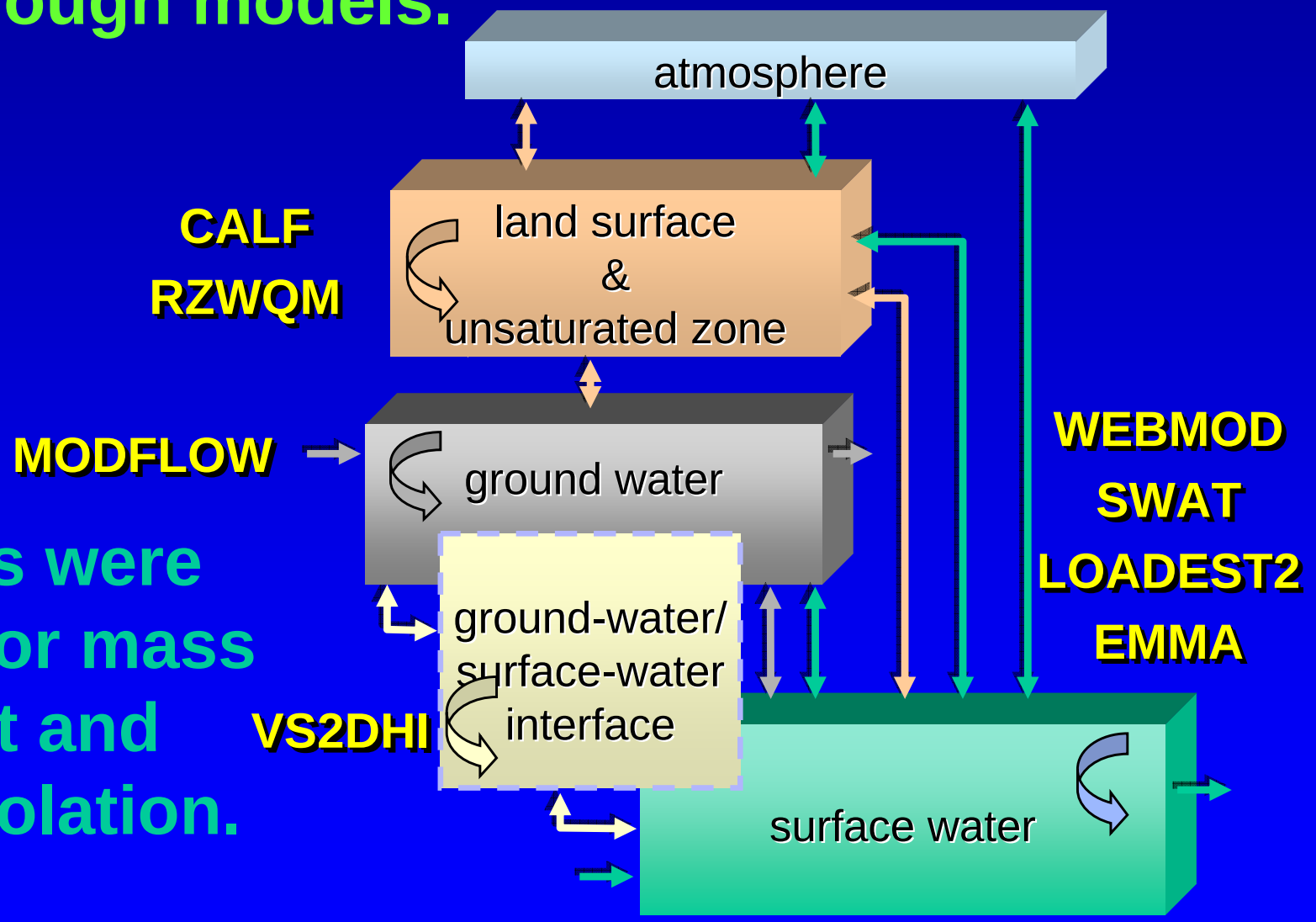
Objectives were met through field observations and through models.



Models were used for mass budget and extrapolation.

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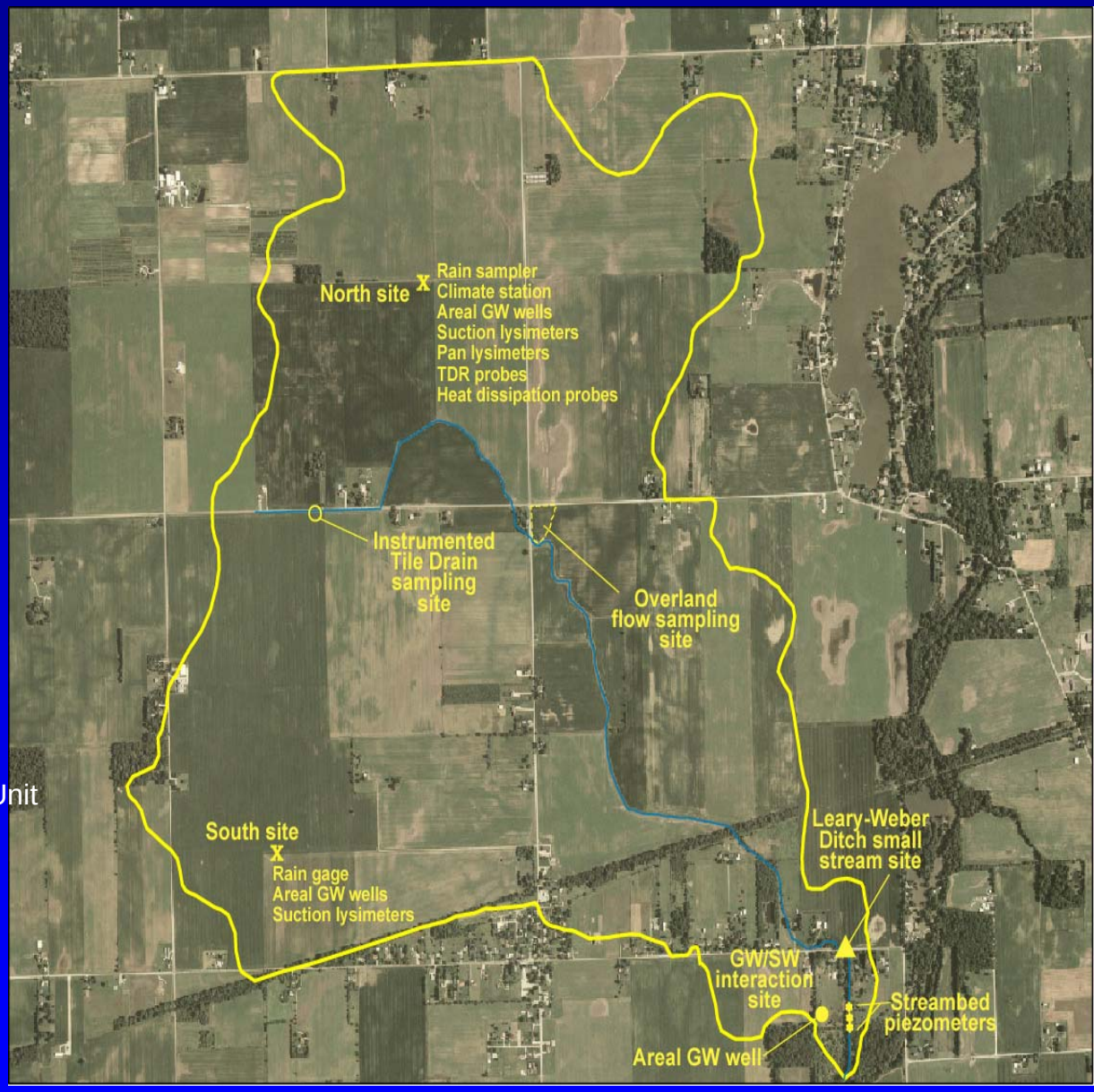

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Indiana: Understanding the Hydrologic System

Tracers and Ag Contaminants

Targeted Analytes

- Water
- Nutrients – dissolved and particulate
- Pesticides – dissolved and particulate
  (triazines, acetanilides, OPs, glyphosate)
- Major Ions, Field Parameters
- Carbon (particulate and dissolved)
- Solids characterization
  (size, bulk density, redox condition)
- Age Dating Tools
  (CFCs, SF_6, Tritium)
- Isotopes
  (nitrogen, oxygen)

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Two Vignettes from ACT:

Indiana: Subsurface Drainage

Wes Stone

John Wilson

Scott Ator

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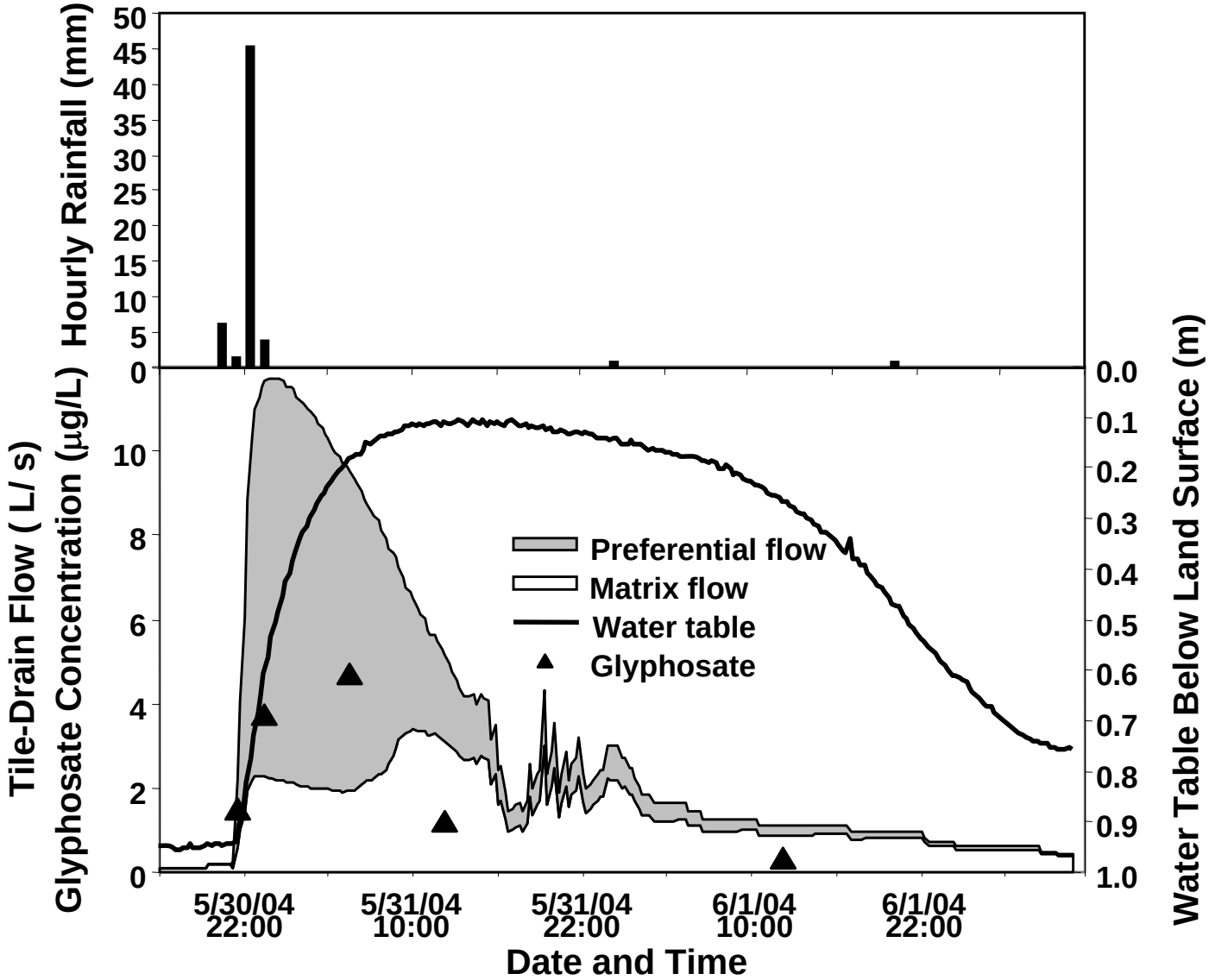
Indiana

Tile Drain flow over one storm event.



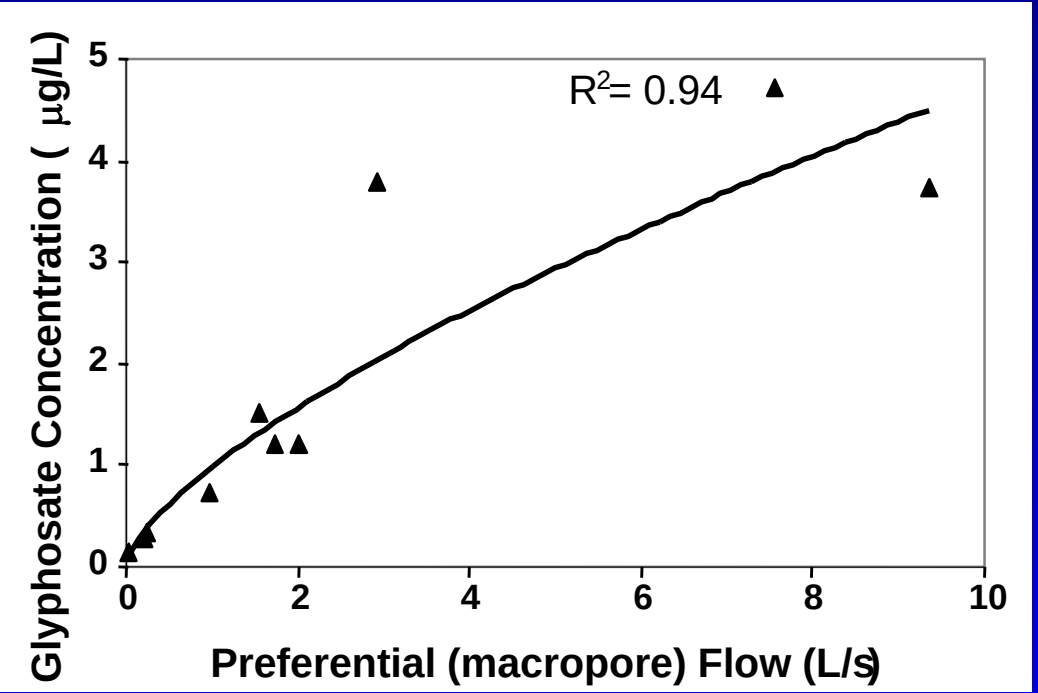
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

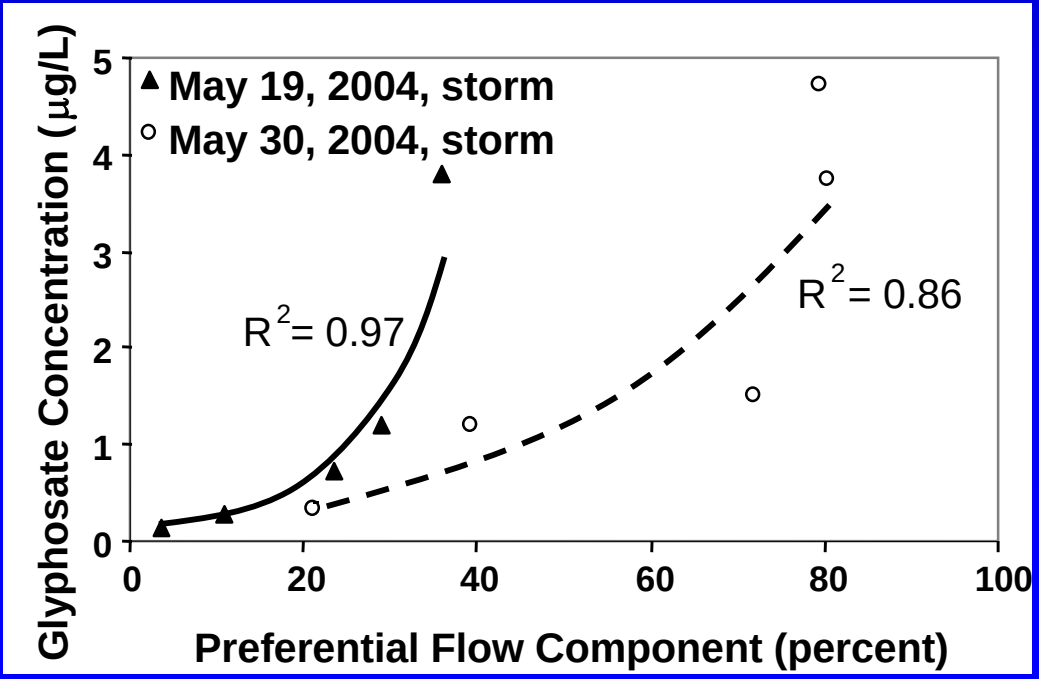
Glyphosate

First storm occurred after glyphosate application.

[Glyphosate] in the tile-drain effluent was related to the amount of preferential flow in the tile-drain flow.

To match concentrations measured in first storm, more preferential flow was required during the second storm.





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Tile drains versus overland flow…

	Glyphosate			
	Max (mg/L)	Min (mg/L)	Mean (mg/L)	n
Tile Drain	4.7	0.15	1.8	10
Overland Flow	427	22	206	12
Leary Weber Ditch	5.5	0.16	1.7	10

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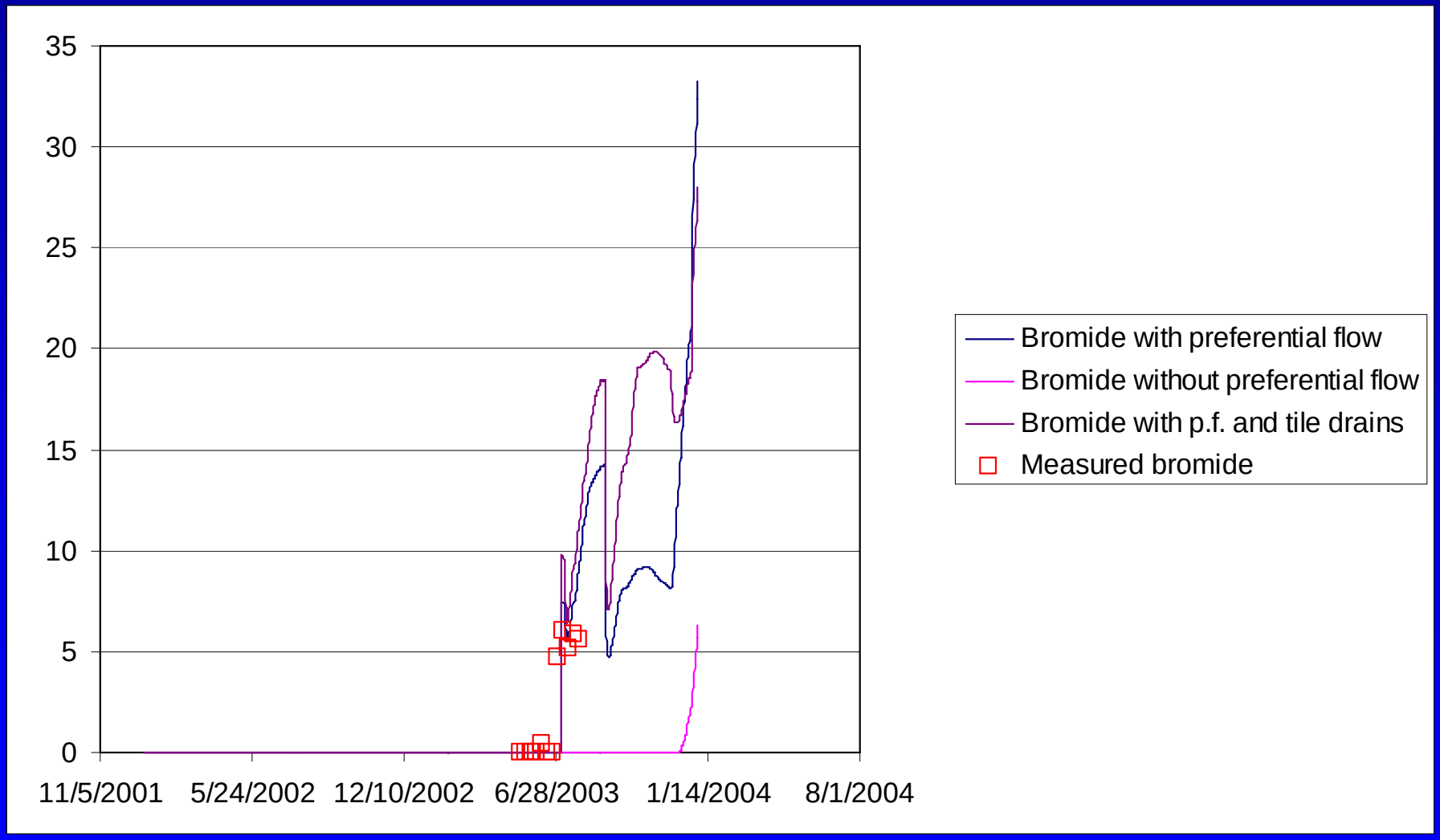
Indiana

Use of tracer and RZWQM for transport validation



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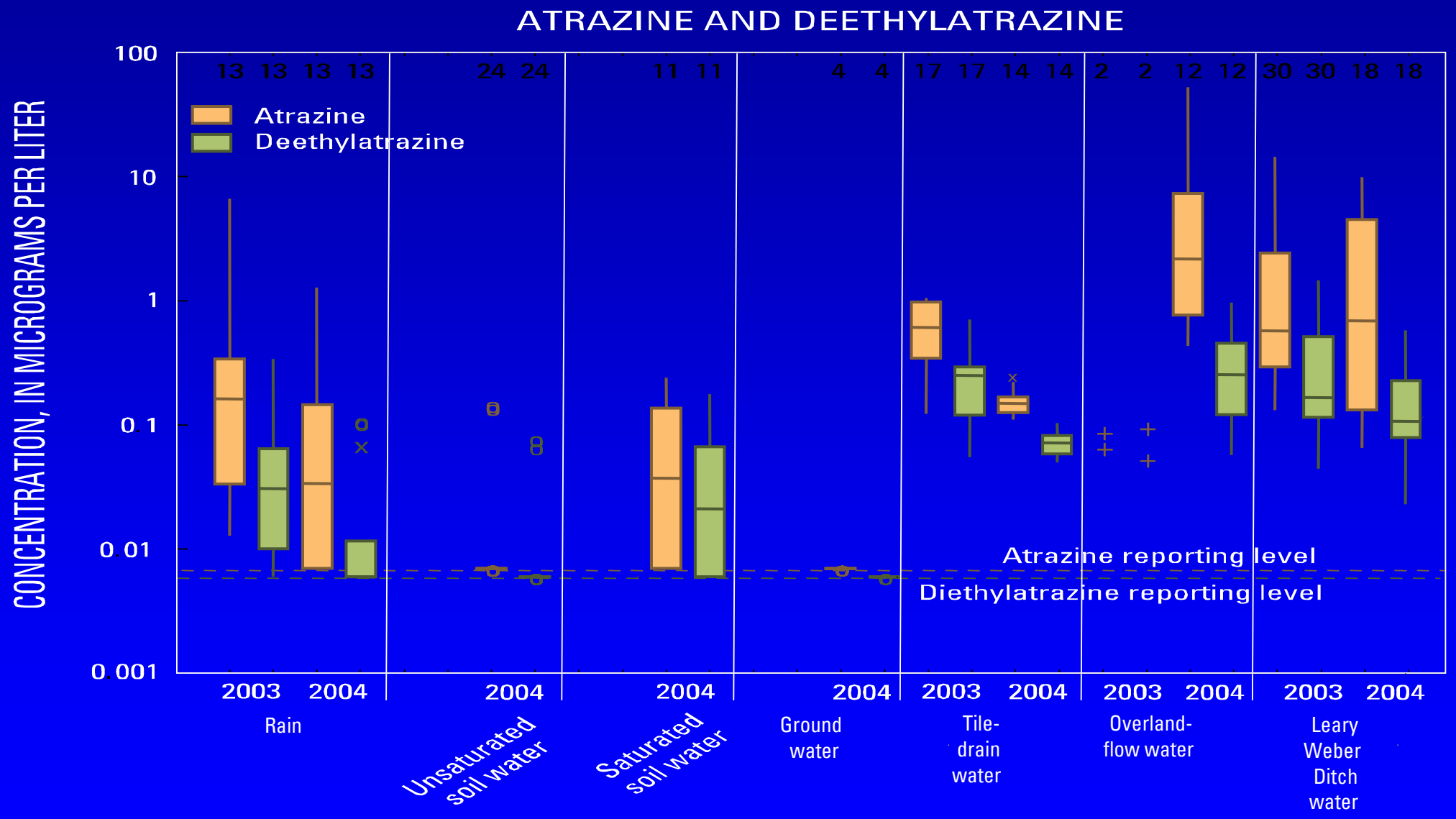
Modelling Assumption

- Does pesticide and nutrient transport behave similarly?
- Should they be modeled the same way?

Atrazine and Deethylatrazine Concentrations



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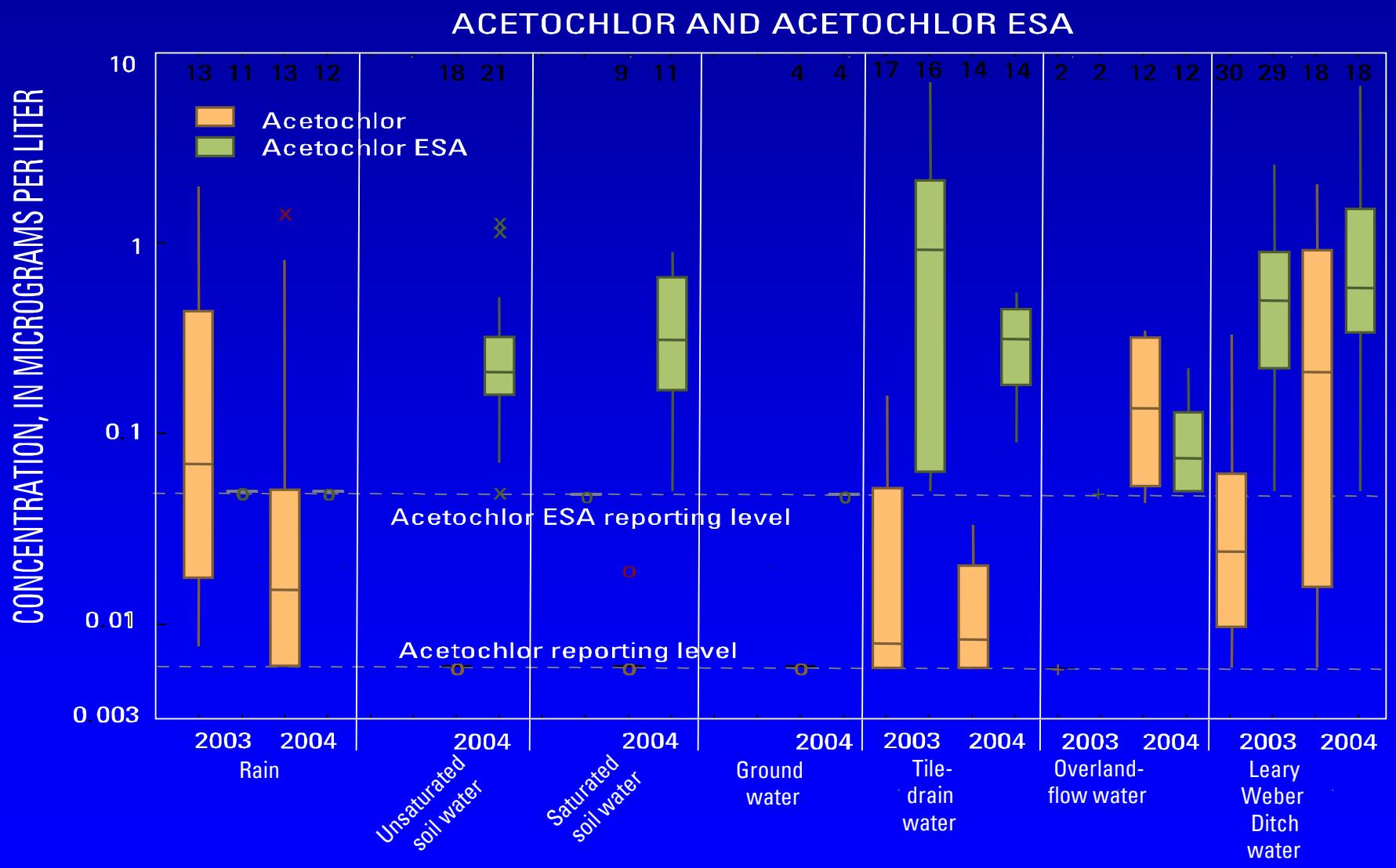
Leary Weber Ditch Study

Acetochlor and Acetochlor ESA Concentrations



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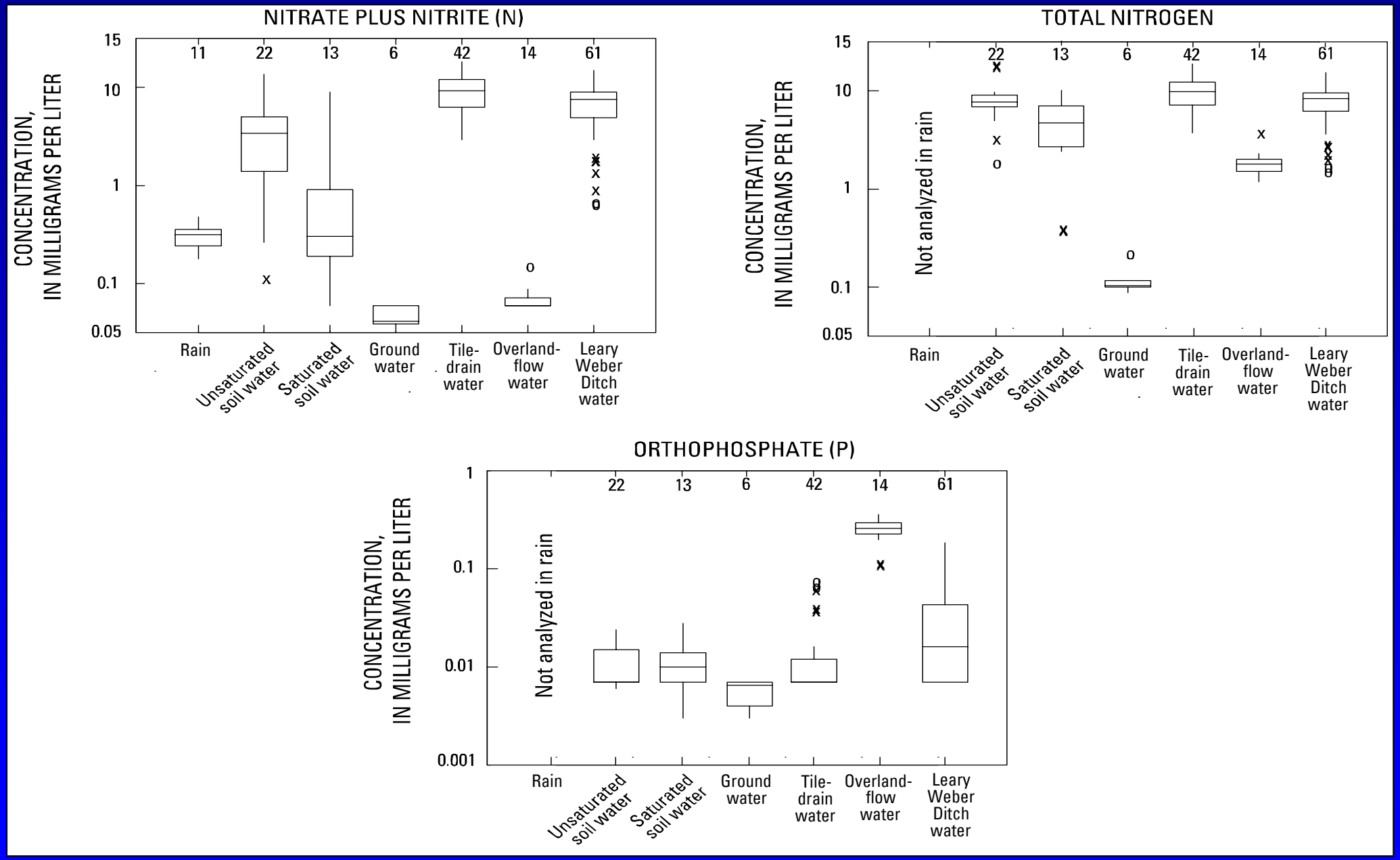
Leary Weber Ditch Study

Selected Nutrient Concentrations



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Leary Weber Ditch Study

Conclusions

- The Leary Weber Ditch example shows how tile-drain flow, specific conductance, and chloride data can help explain the transport of glyphosate to the tile drain.
- Presence of preferential (macropore) flow increases the significance of tile drains as agrichemical-transport pathways to streams.
- Overland flow, when present, can transport higher concentrations of glyphosate than do tile drains.
- Tile drains transport higher concentrations of nitrate.

Two Vignettes from ACT: Lag Times

Dave Wolock, Josh Linard

Lag time is the travel time of water and chemicals from the land surface to the stream.

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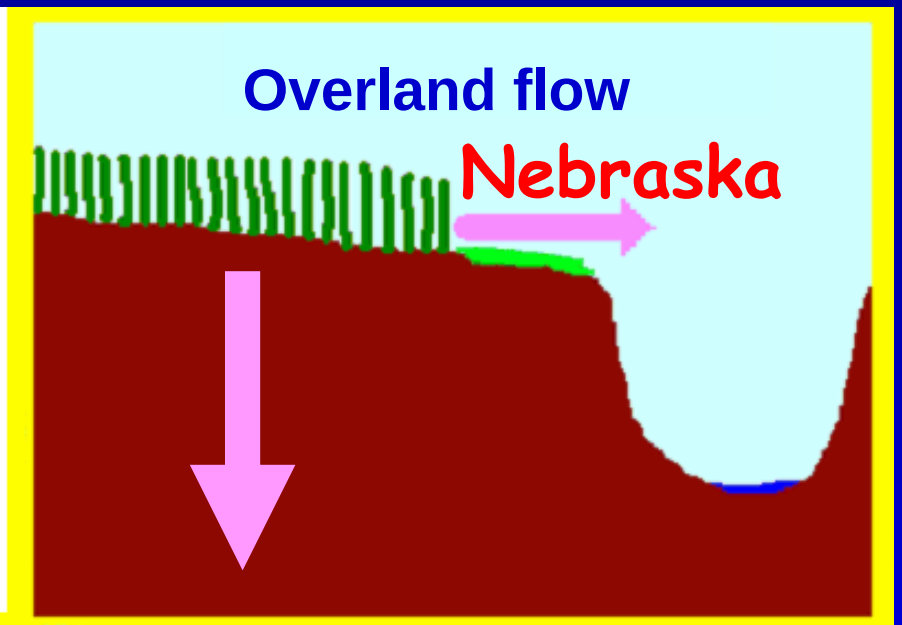
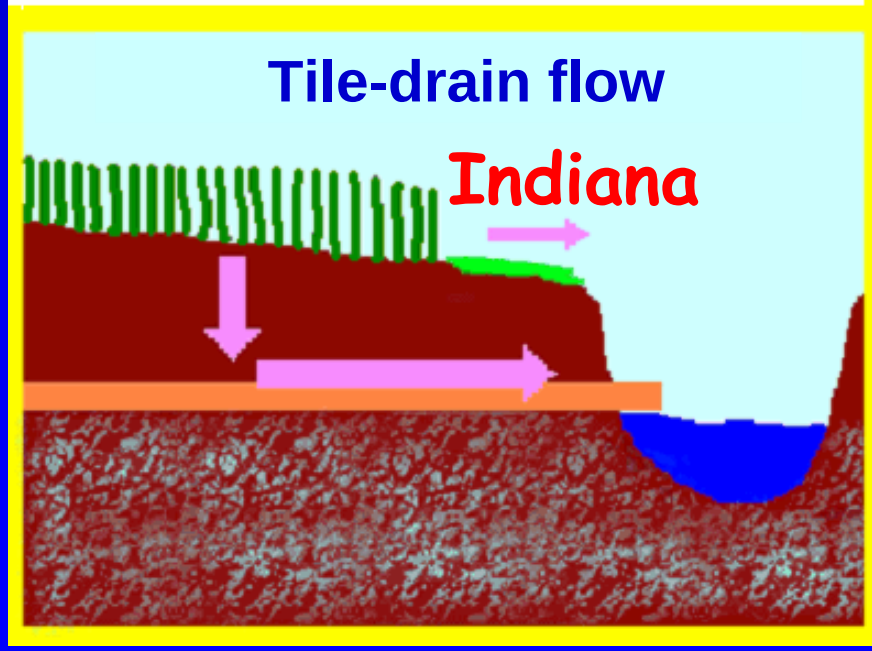
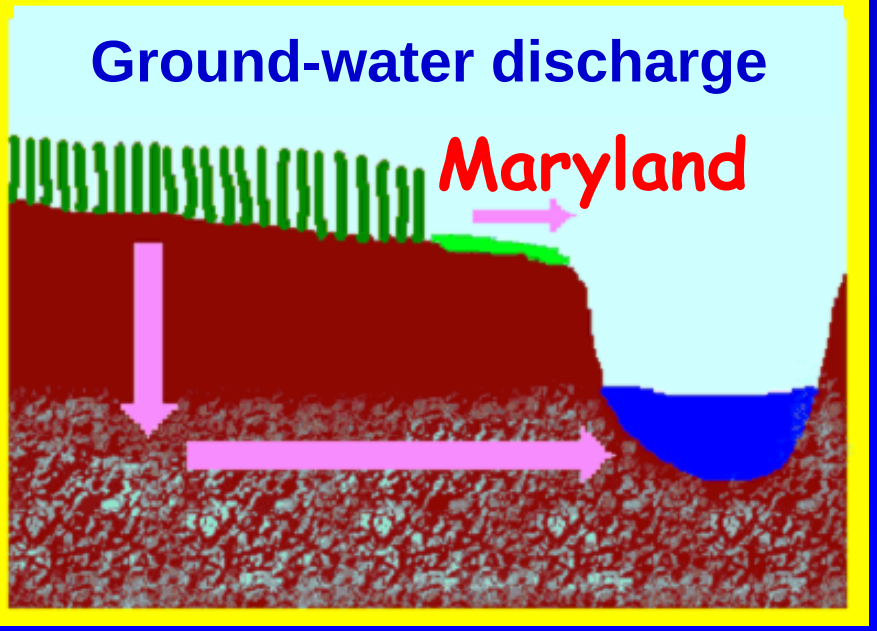
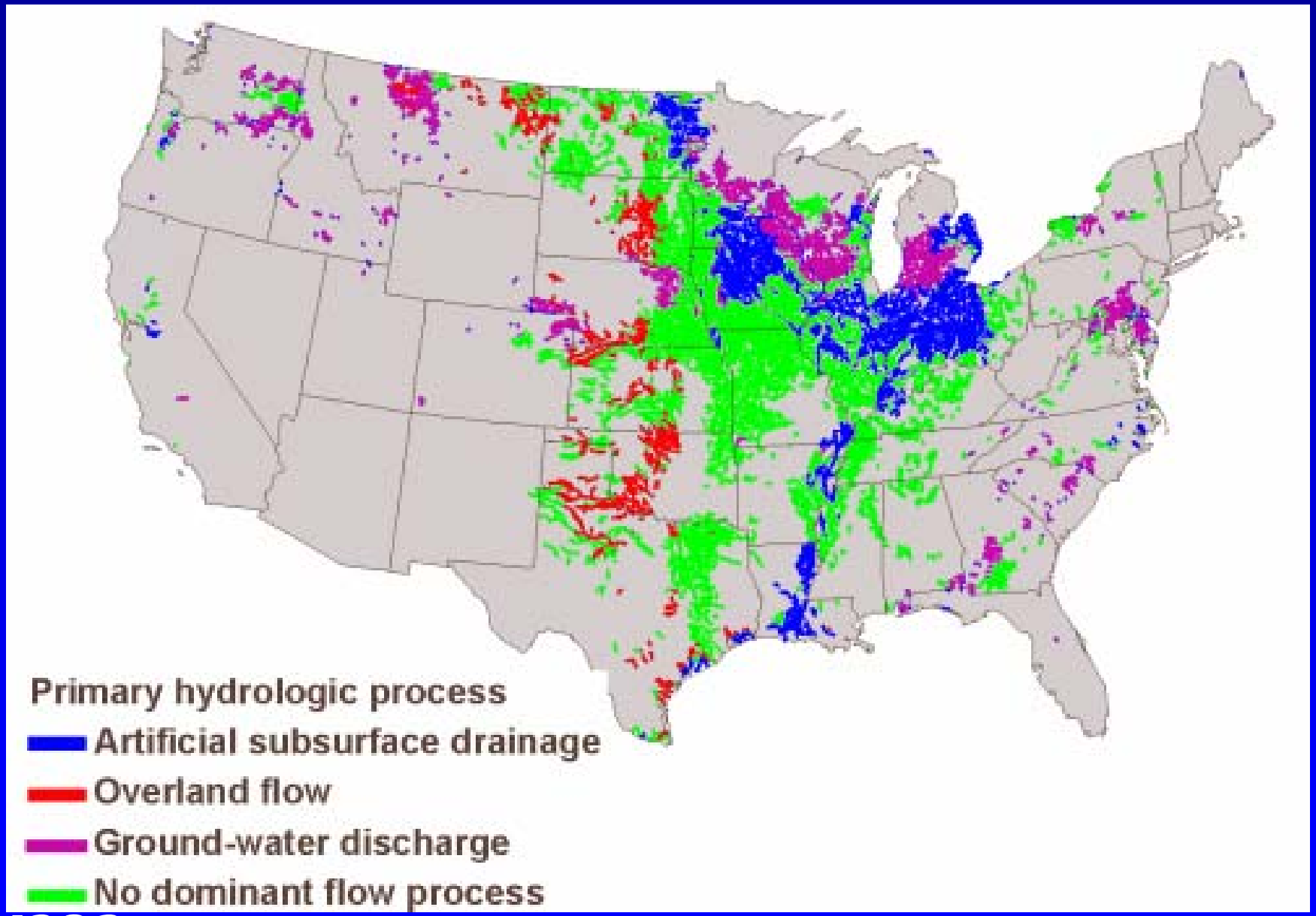
Transport and lag times vary in different hydrologic systems.







Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



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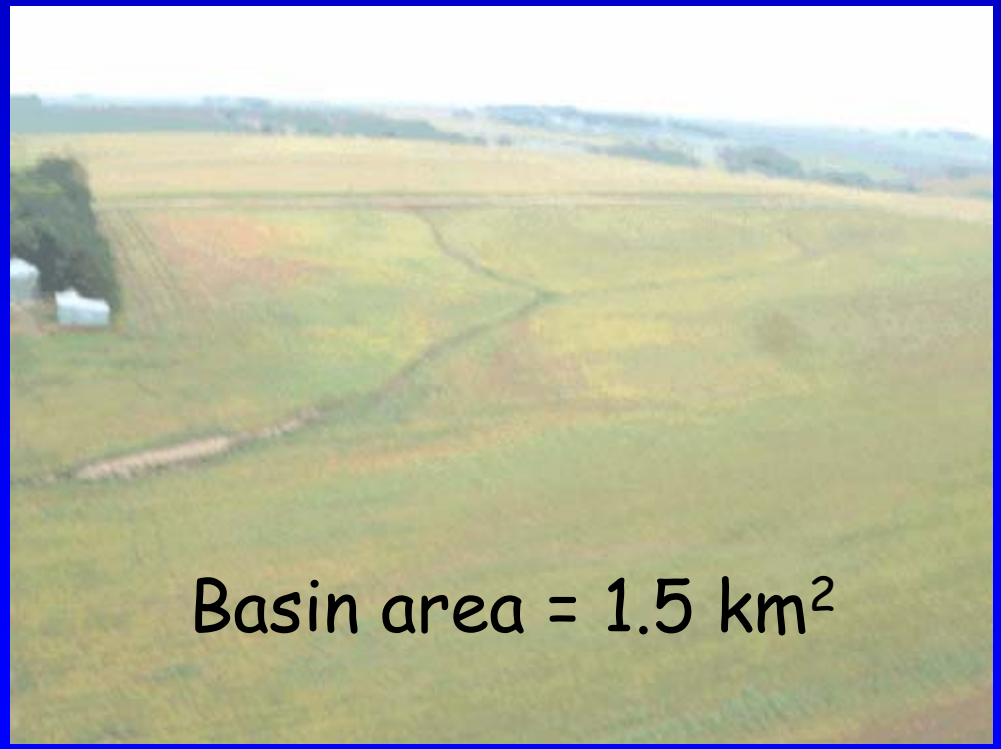
Nebraska site



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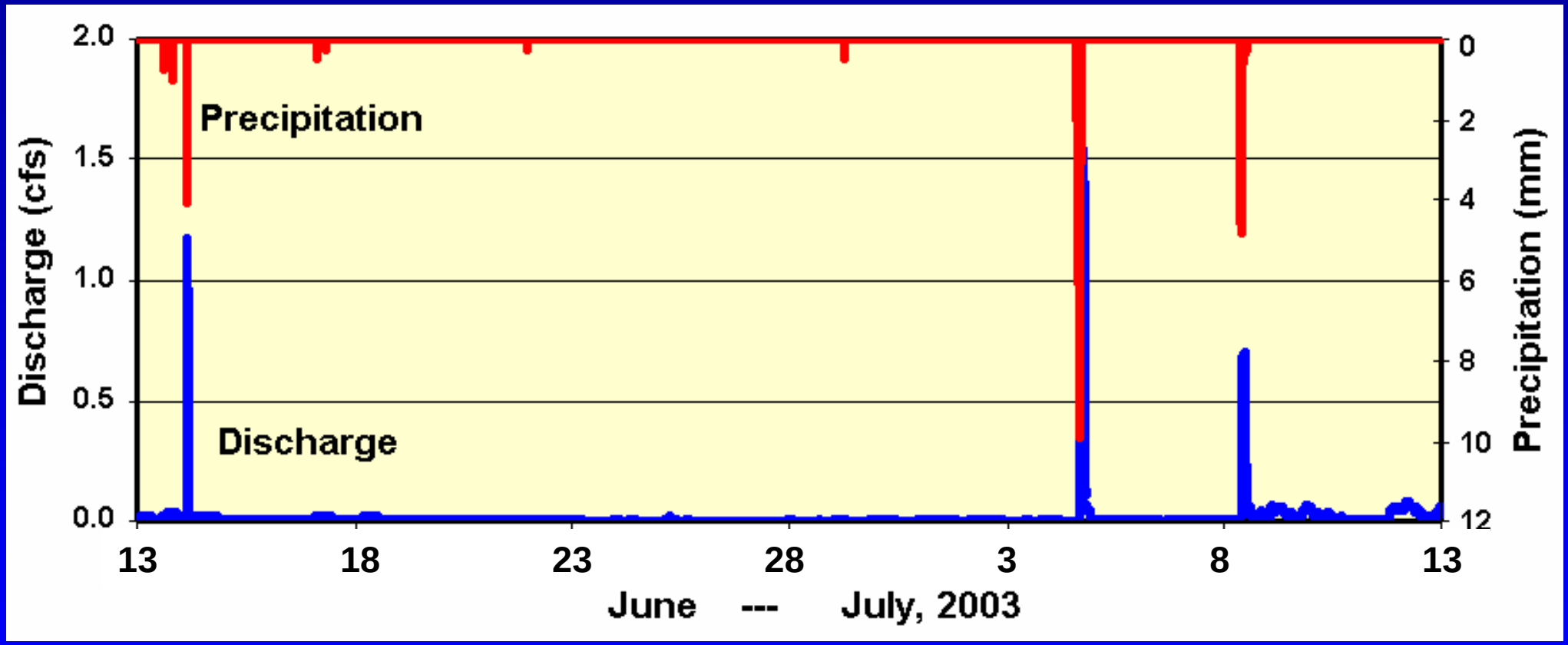
Nebraska: Overland-flow-dominated streamflow

Nebraska: Overland-flow-dominated streamflow



Typical flow event lasts 1-2 hours.

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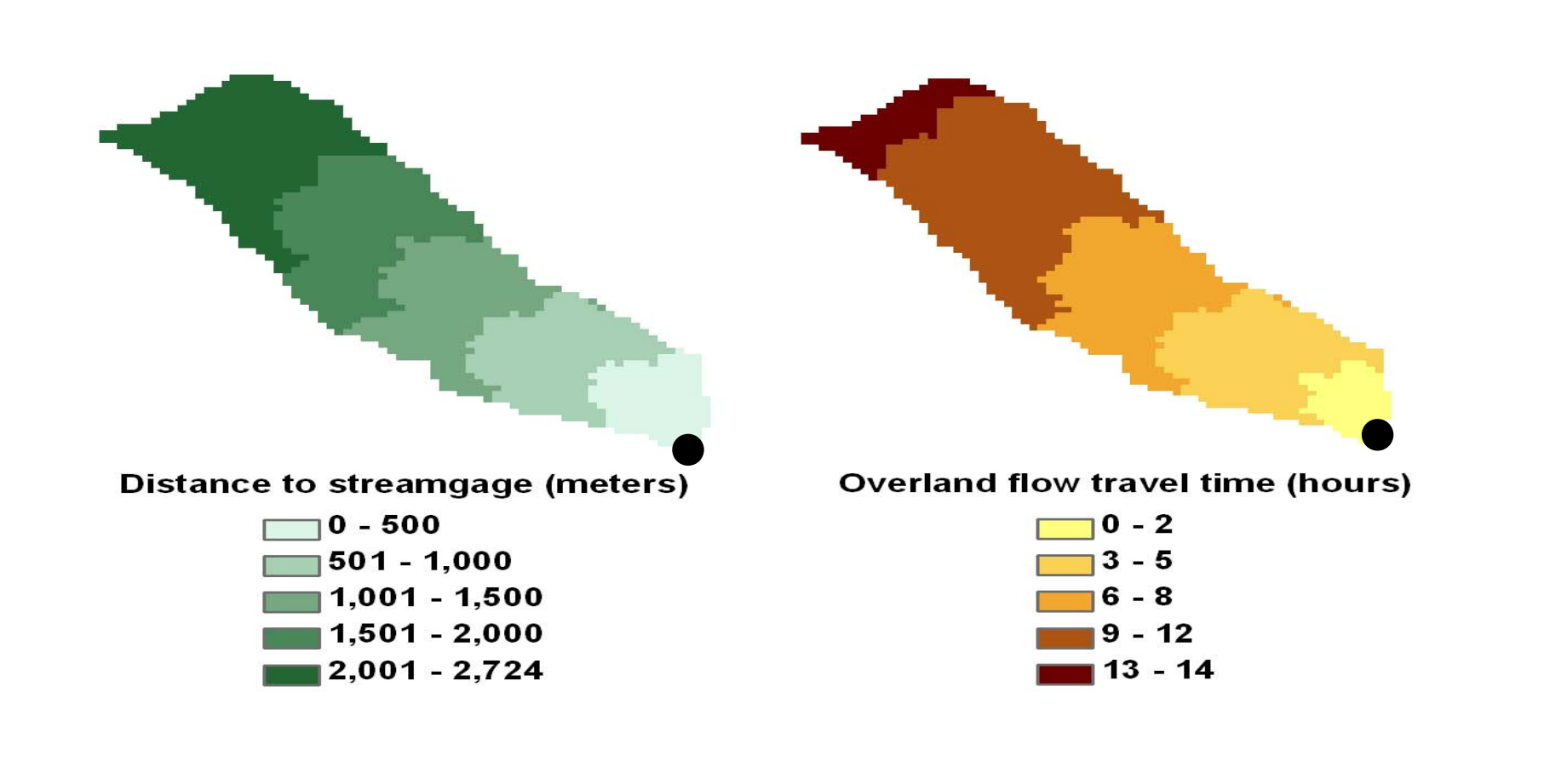

- Assume overland flow velocity is 200 m/hr
- Typical flow event lasts 1-2 hours
- About 10% of the watershed has a travel time < 2 hours

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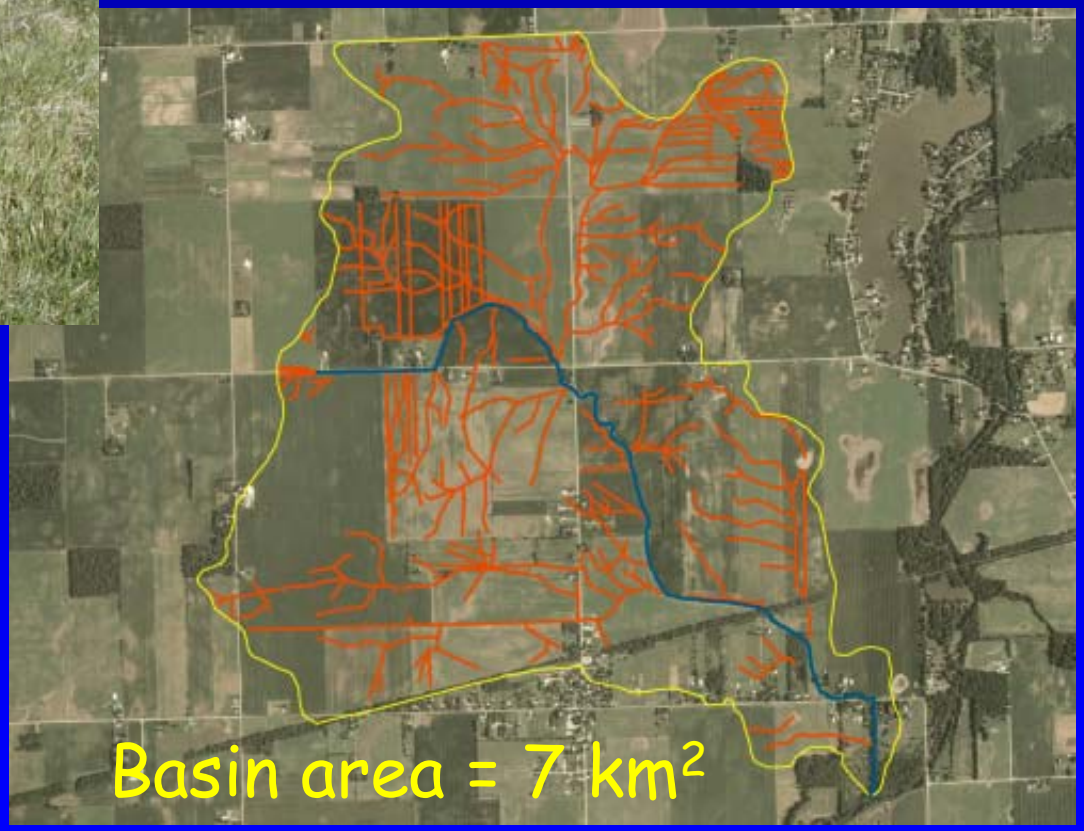
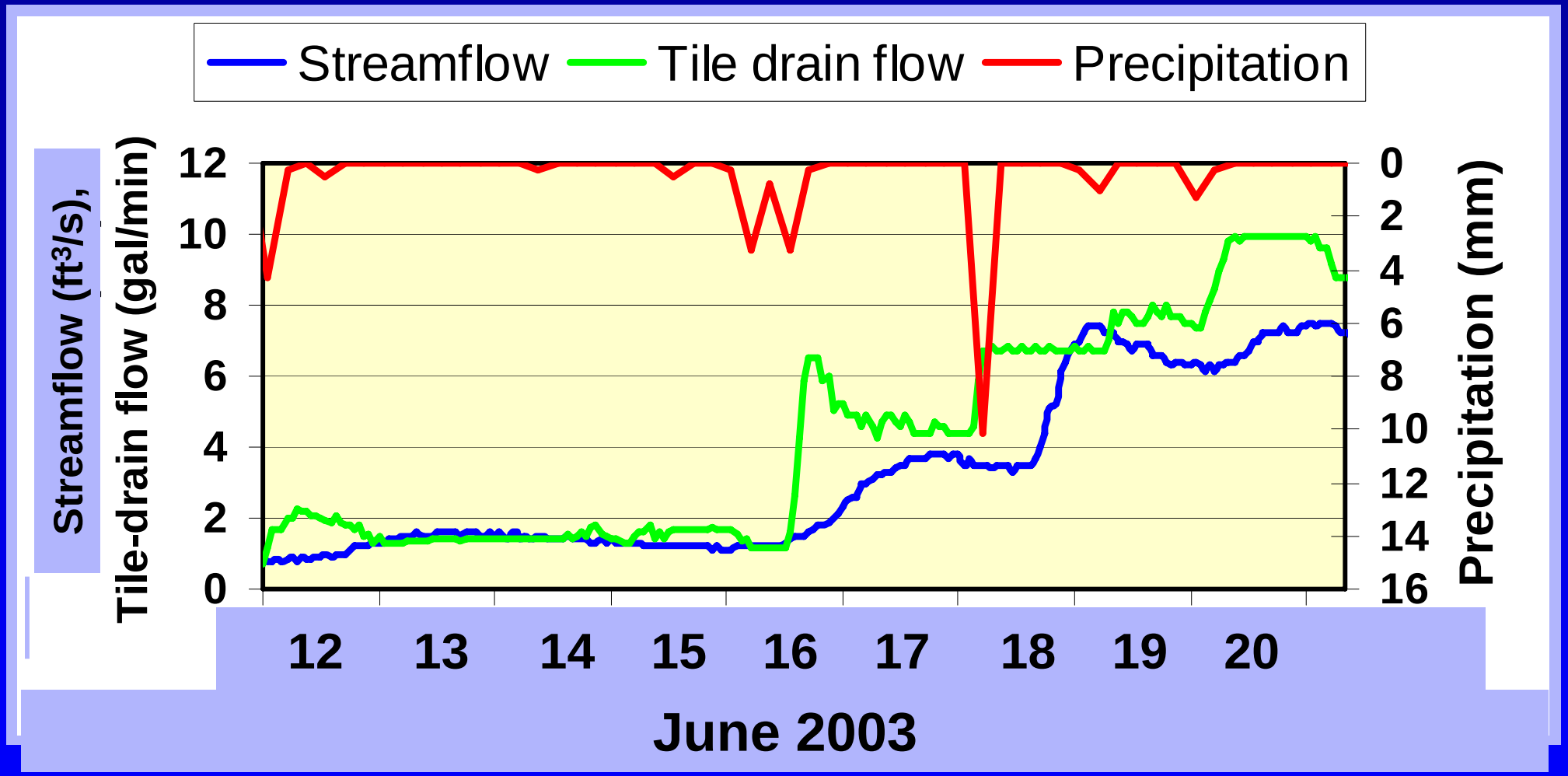
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



USGS **Indiana: Tile-drain-dominated streamflow**

Indiana: Tile-drain-dominated streamflow



Typical flow event lasts 24-48 hours.

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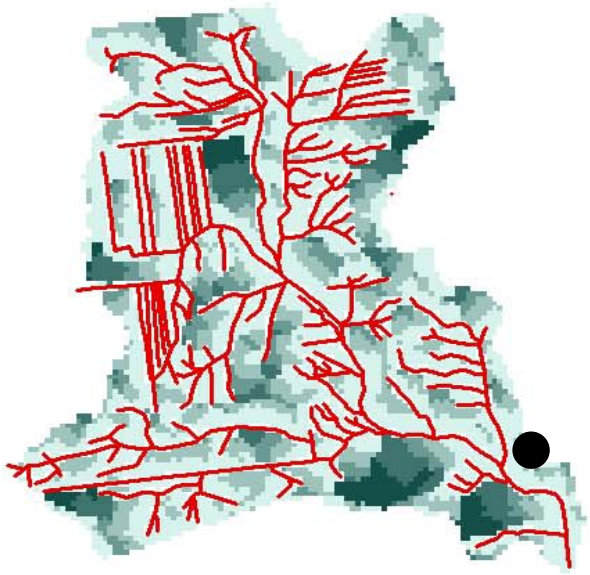

Distance to tile drain (m)

- 0 - 100
- 101 - 200
- 201 - 300
- 301 - 500
- 501 - 964

Travel time to tile drain (hours)

- 0 - 8
- 9 - 16
- 17 - 24
- 25 - 32
- 33 - 48

- Assume rapid subsurface flow velocity is 20 m/hr
- Typical flow event lasts 24-48 hours
- The entire watershed has a travel time < 48 hours

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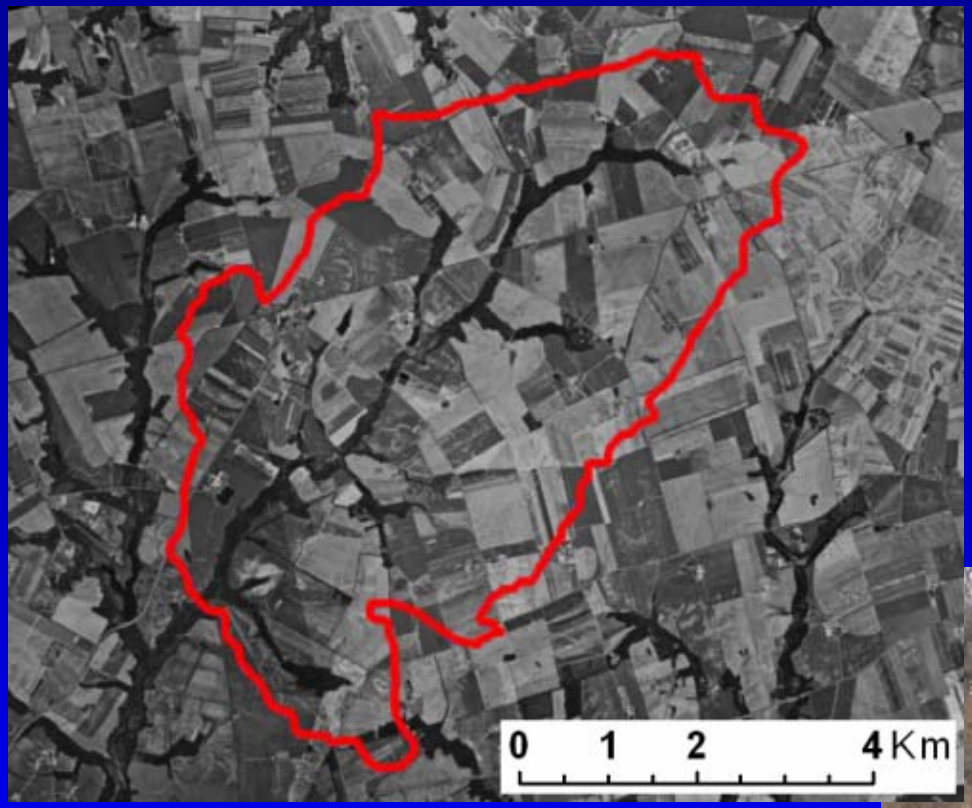
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



Maryland: Ground-water discharge dominated streamflow

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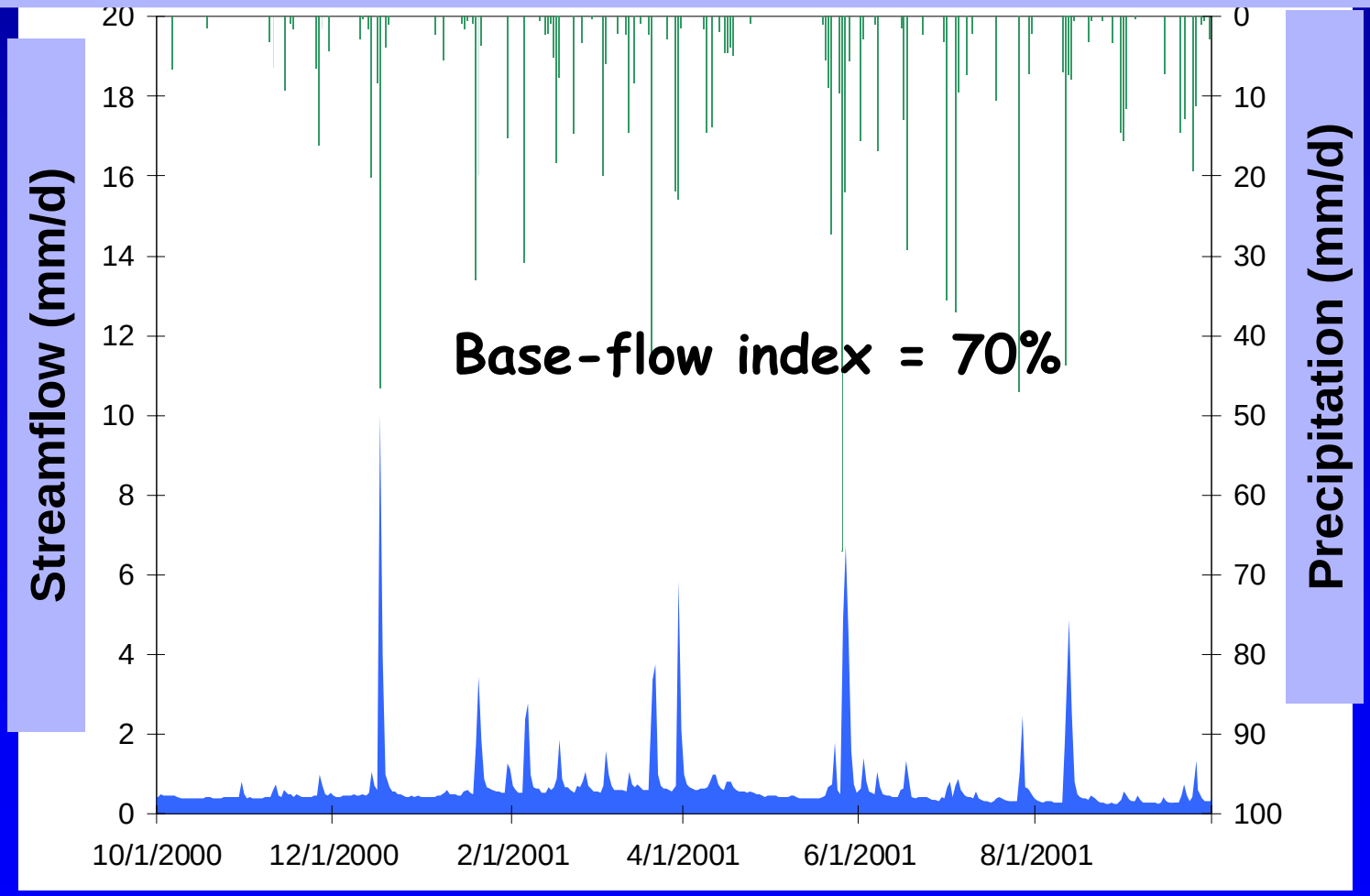
Maryland: Ground-water discharge dominated streamflow



Ground-water discharge to stream is continuous.

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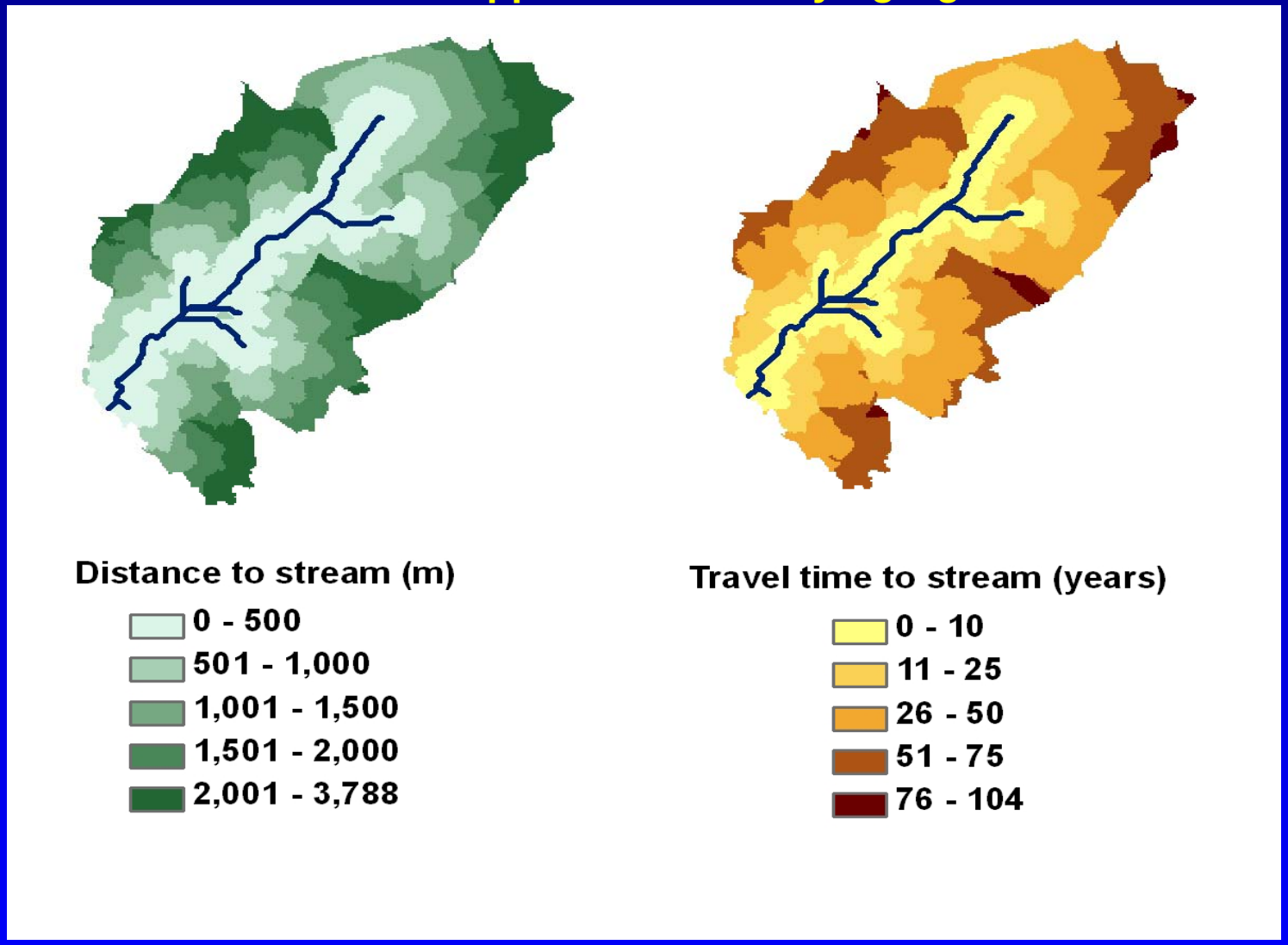

- Assume ground-water flow velocity is 0.1 m/day
- Ground-water discharge to stream is continuous.
- The entire watershed is a source of streamflow.

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Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

	Nebraska: Overland flow	Indiana: Tile drains	Maryland: Ground water
Lag time	Hours	Hours	Decades
Degradation potential	Low	Low	High
Fraction of basin contributing to streamflow	Small	Large	Large
Age of streamflow	Young	Young	Old

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Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

	Nebraska: Overland flow	Indiana: Tile drains	Maryland: Ground water
Response to changes in chemical applications	Quick	Quick	Slow
Minimum tillage effective?	Yes	No	No
Buffer zones near stream effective?	Yes	No	No

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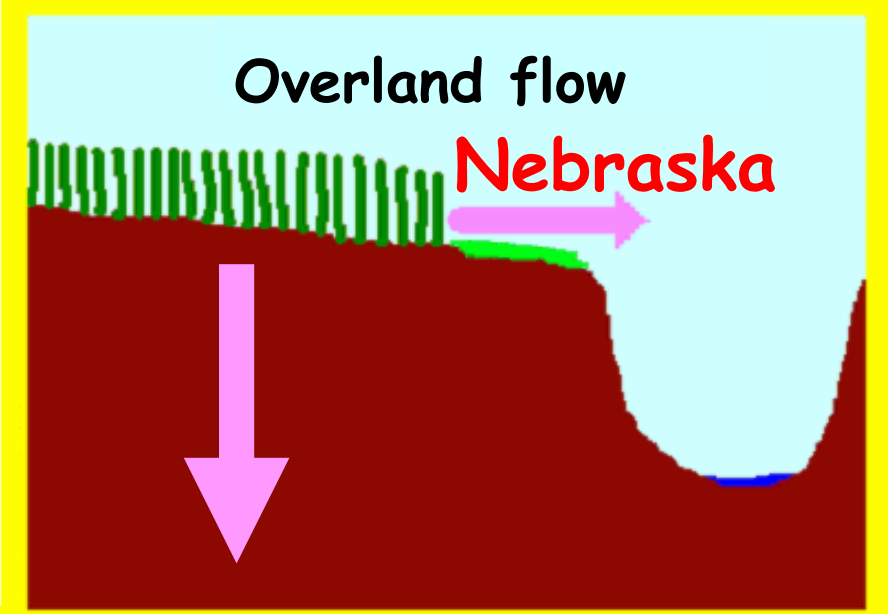
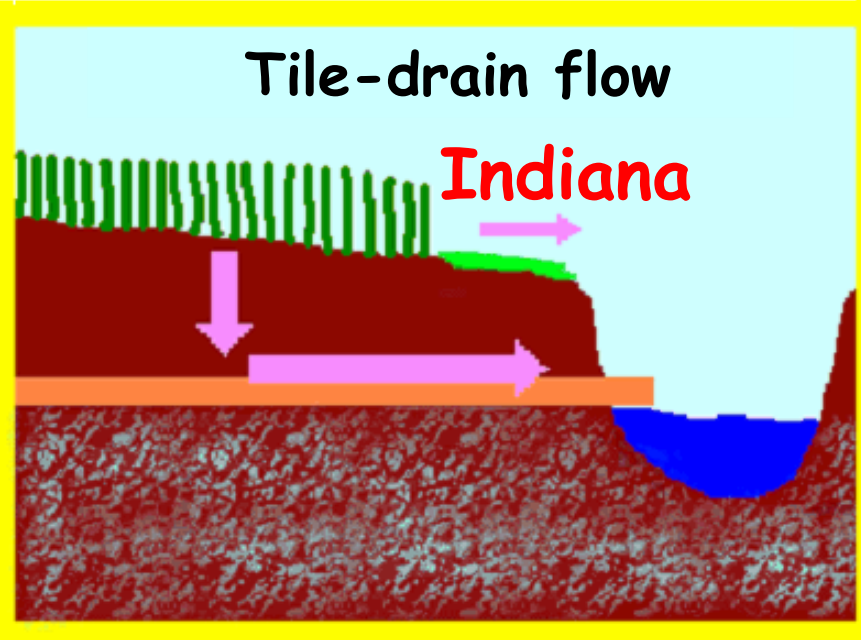
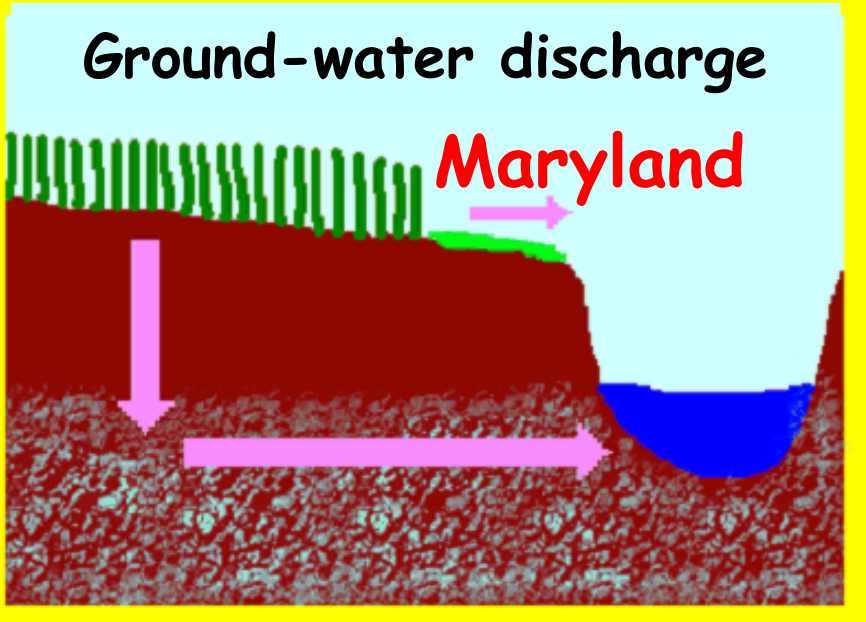
Conclusion

Hydrology matters for managing agricultural chemicals.







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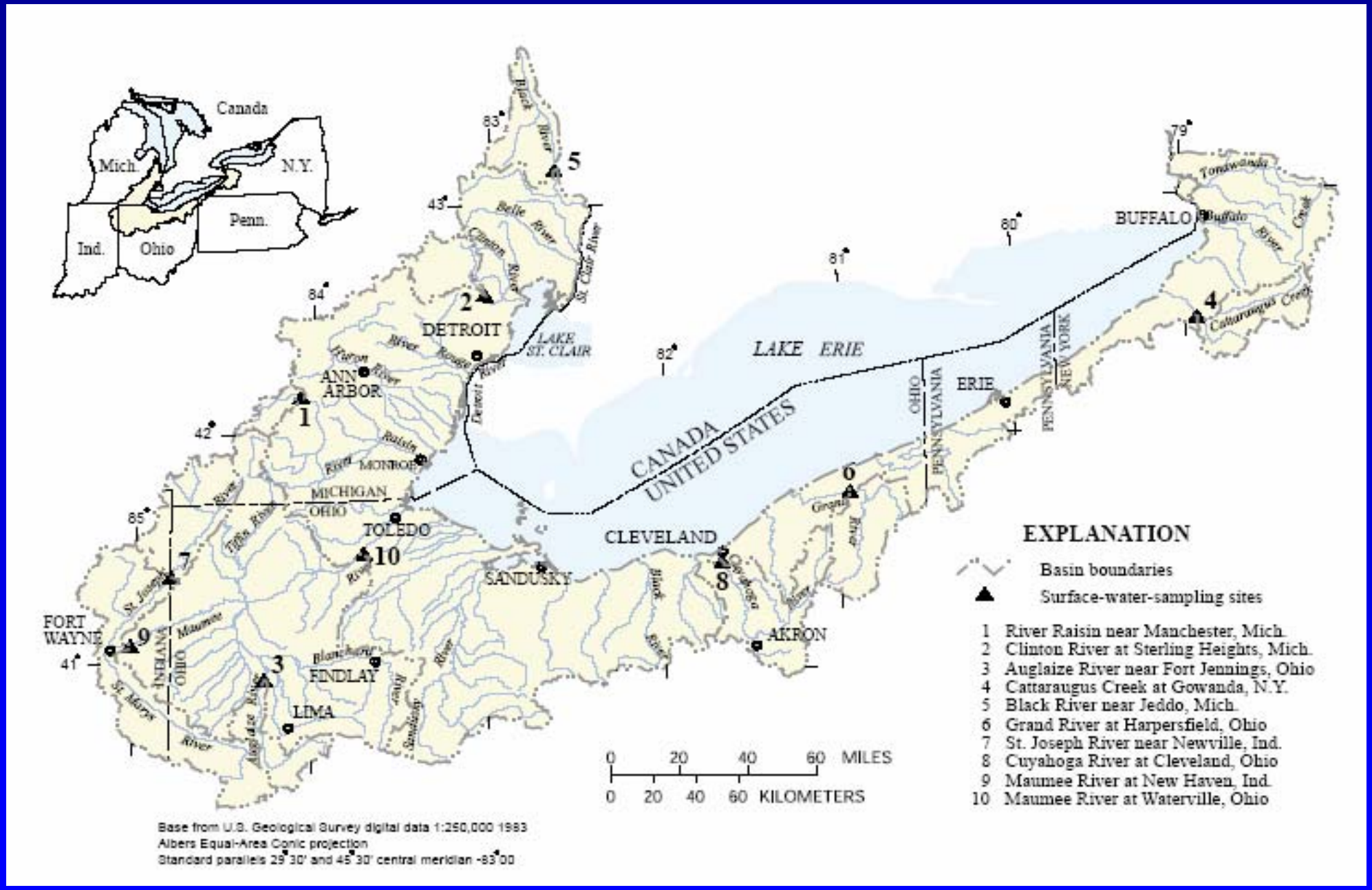
Lake Erie NAWQA Information

Sampling sites

- St. Joseph River nr Newville, Ind. (04178000)
- Auglaize River nr Fort Jennings, Ohio (04186500)
- Maumee River at Waterville, Ohio (04193500)

Lake Erie NAWQA Sampling Locations



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Lake Erie Study

Range of Atrazine Concentrations and Use, 1996-98

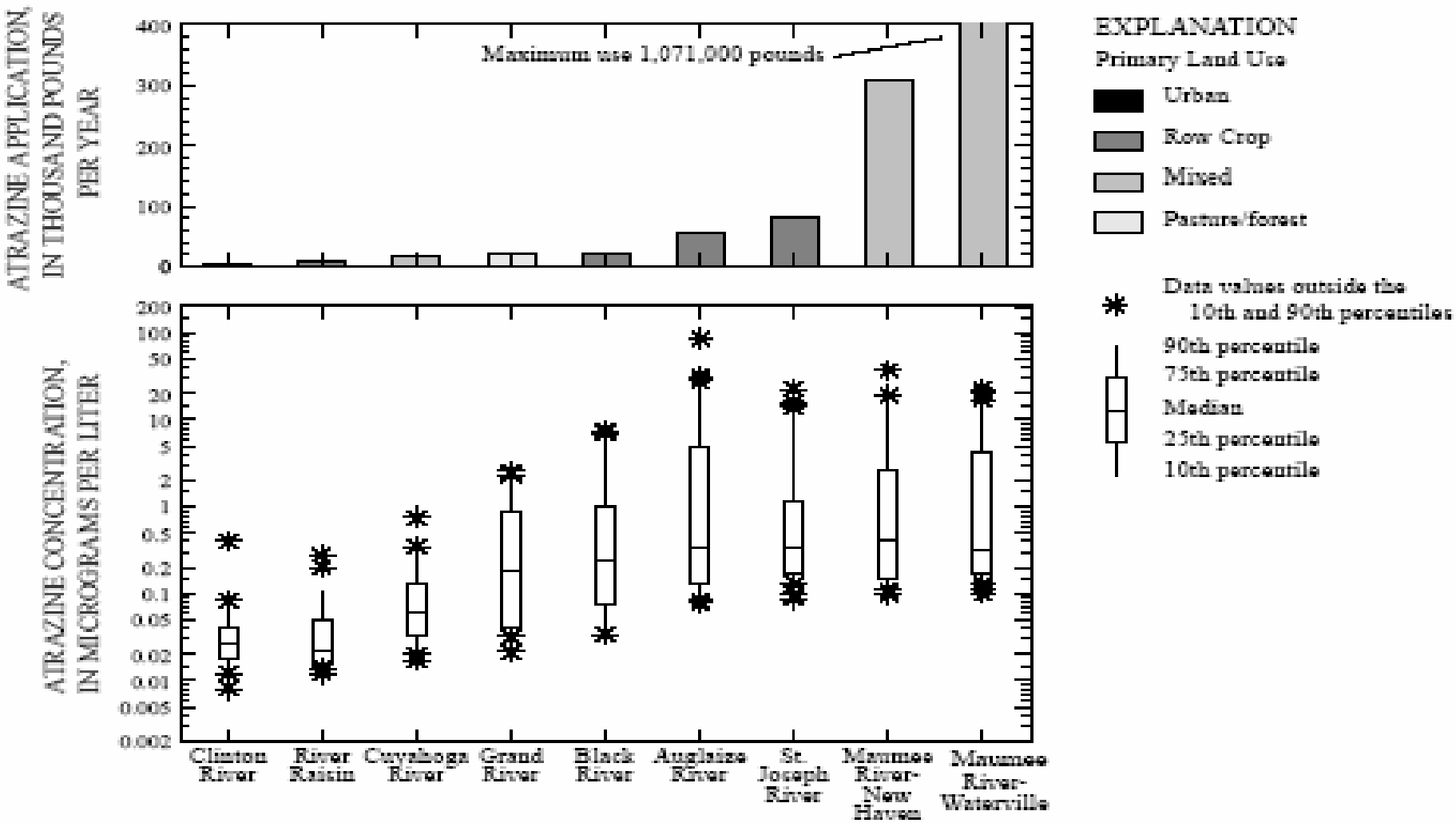

Figure 17. Atrazine application in 1997 and concentrations, by site. Lake Erie-Lake St. Clair River Basin surface-water-sampling sites listed in of order increasing application of atrazine. (Application data from National Agricultural Statistics Service, 1999.)

Loads and Yields of Selected Herbicides, 1996-98

Table 7. Estimated pesticide application in 1997 and summary of loads and yields calculated March 1996 to February 1998 per drainage area of selected pesticides in Lake Erie-Lake St. Clair Basin surface-water-sampling sites

[mi^2, square mile; lb/yr, pound per year; $lb/mi^2/yr$, pound per square mile per year; -- , insufficient number of detections to determine loads and yields; nd, no data]

		Acetochlor				Alachlor				Atrazine			
Site name	Drainage area (mi^2)	Estimated amount of pesticide applied to corn and soybeans in 1997[a] (pounds)	Load (lb/yr)	Standard deviation of load (lb/yr)	Yield per drainage area[b] ($lb/mi^2/yr$)	Estimated amount of pesticide applied to corn and soybeans in 1997[a] (pounds)	Load (lb/yr)	Standard deviation of load (lb/yr)	Yield per drainage area[b] ($lb/mi^2/yr$)	Estimated amount of pesticide applied to corn and soybeans in 1997[a] (pounds)	Load (lb/yr)	Standard deviation of load (lb/yr)	Yield per drainage area[b] ($lb/mi^2/yr$)
River Raisin near Manchester, Mich.	132	5,200	2.0	0.66	0.02	400	1.5	0.40	0.01	10,000	8.4	1.6	0.06
Clinton River at Sterling Heights, Mich.	309	1,200	13	7.7	.04	100	5.1	1.6	.02	2,500	22	5.5	.07
Auglaize River near Fort Jennings, Ohio	332	22,000	660	550	2.0	6,600	620	510	1.9	57,000	4,700	2,900	14
Cattaraugus Creek at Gowanda, N.Y.	436	nd	--	--	--	nd	--	--	--	nd	100	13	.23
Black River near Jeddo, Mich.	464	12,000	260	260	.55	800	110	88	.24	23,000	1,200	950	2.5
Grand River at Harpersfield, Ohio	552	7,600	84	73	.15	1,400	27	14	.05	19,000	440	260	.79
St. Joseph River near Newville, Ind.	610	34,000	11,000	14,000	17	6,200	1,600	1,400	2.6	79,000	8,400	5,800	14
Cuyahoga River at Cleveland, Ohio	788	7,000	140	950	.18	1,500	37	15	.05	18,000	260	66	.33
Maumee River at New Haven, Ind.	1,967	120,000	6,600	5,500	3.3	26,000	2,900	2,200	1.5	310,000	22,000	15,000	11
Maumee River at Waterville, Ohio	6,330	420,000	12,000	6,600	1.9	110,000	8,000	4,000	1.3	1,100,000	47,000	21,000	7.5

Other NAWQA Modelling Efforts

- **SPARROW**
  (SPAtially Referenced Regression On Watershed Attributes)
- **WARP**
  (Watershed Regressions for Pesticides)

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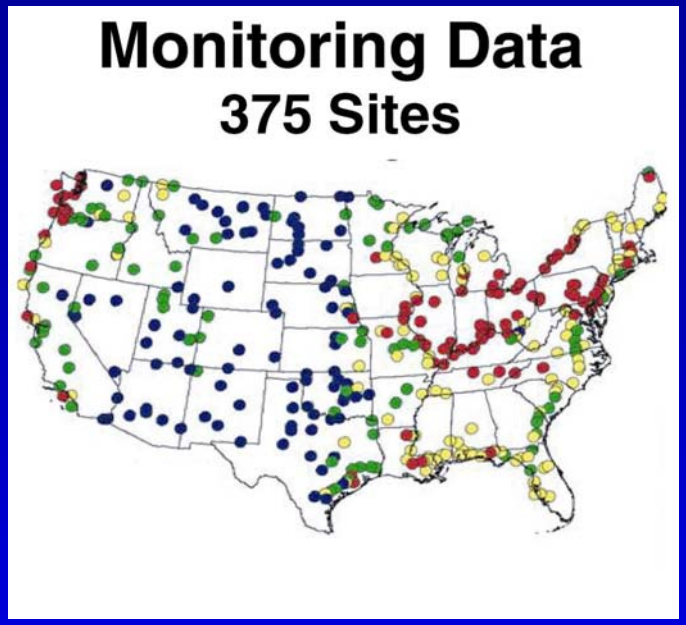
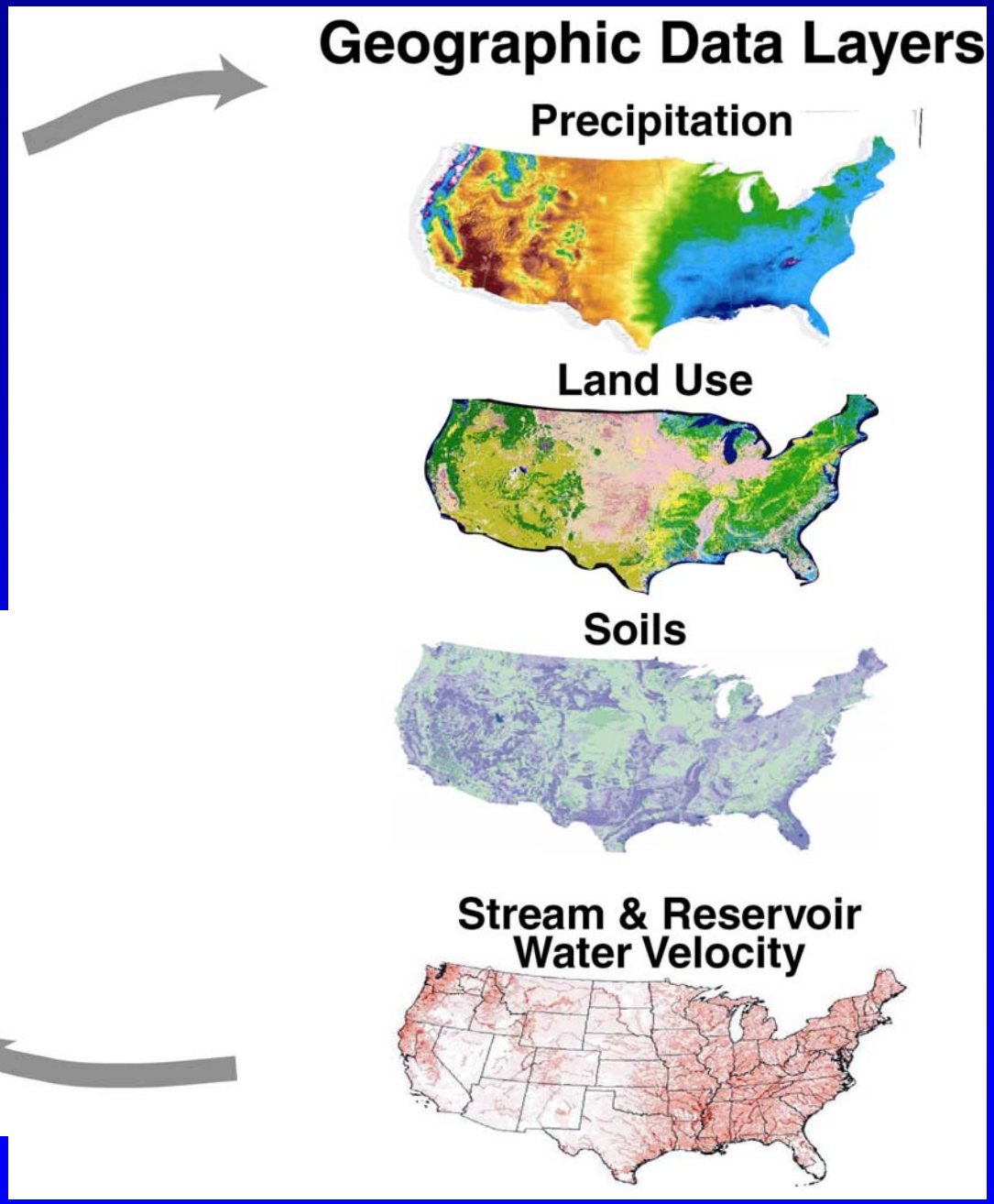
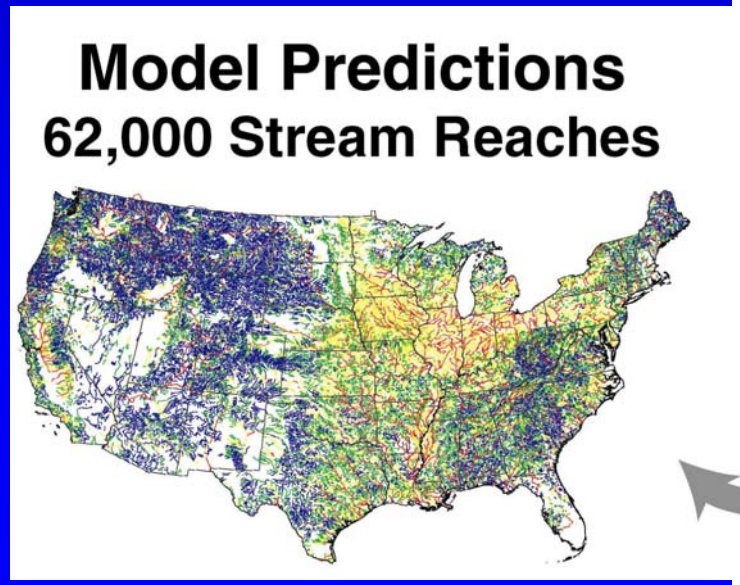
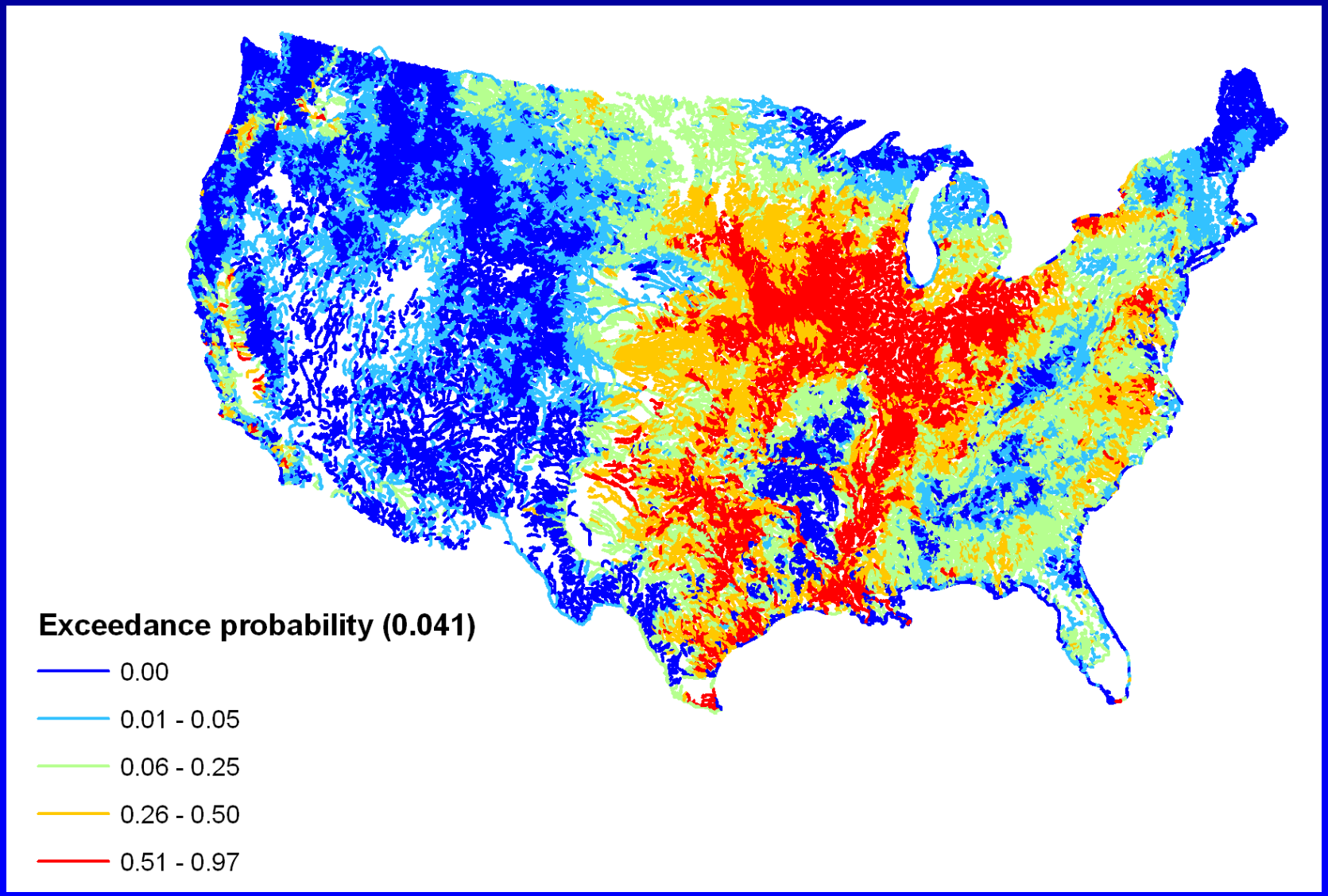
SPARROW Model Framework







Probability that 95th percentile chlorpyrifos concentration exceeds 4-day moving average ambient water-quality criteria for aquatic life



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WARP Model

THE END

Contacts:

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- Jeff Frey, White River-Miami River Study Chief,
  jwfrey@usgs.gov (317) 290-3333 x.151
- Mike Yurewicz, NAWQA Regional Hydrologist
  mcyurewi@usgs.gov (703) 648-5811

NAWQA Websites:

http://water.usgs.gov/nawqa/
http://in.water.usgs.gov/NAWQAWHMI/act_map.php/
http://www.epa.gov/oppefed1/models/water/vadose_zone_04oct2004.htm#calf

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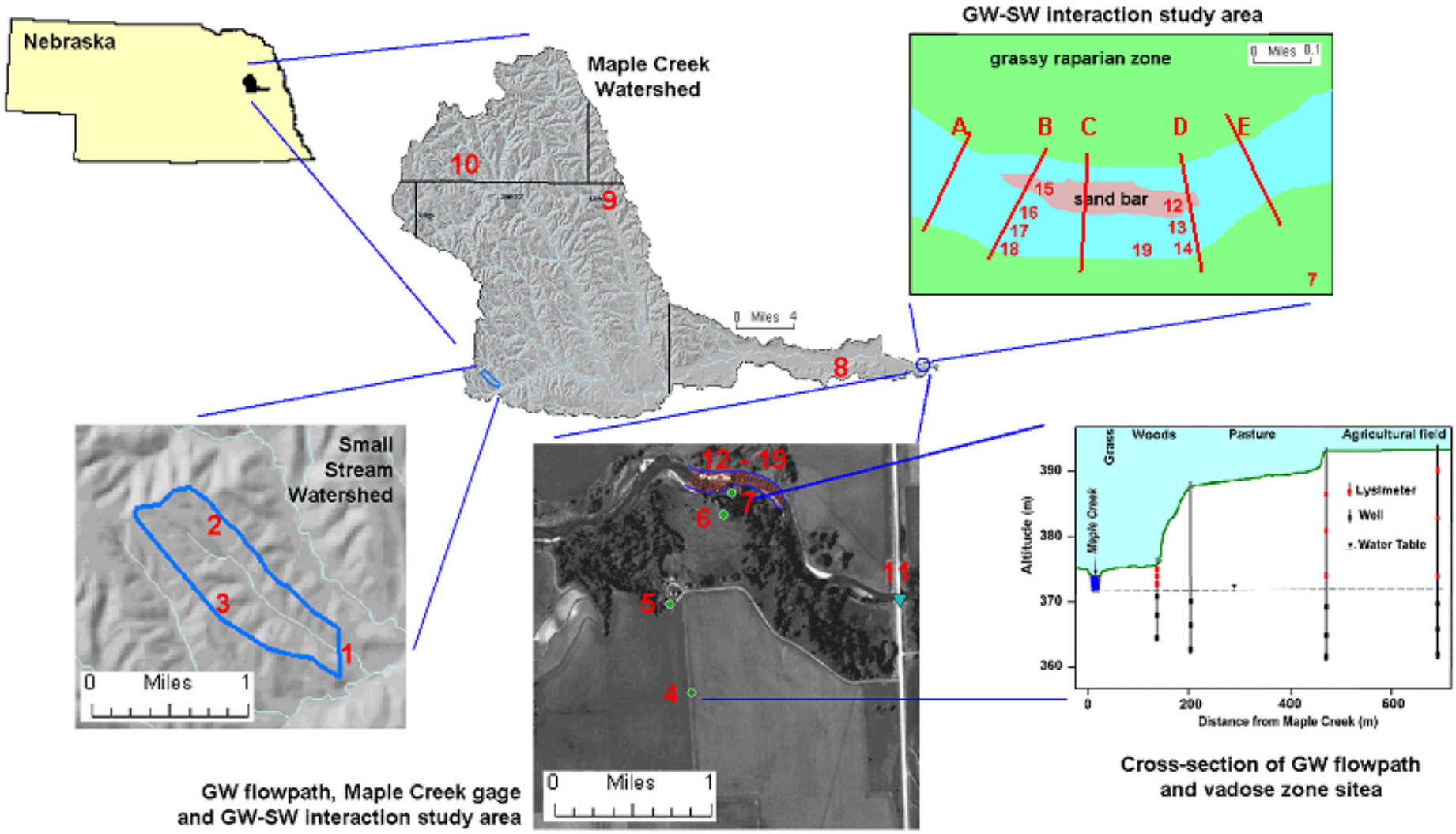
Study Design: Nebraska



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Four Vignettes from ACT

3. GW-SW Interactions

Hedeff Essaid, Kathy McCarthy, Jason Vogel

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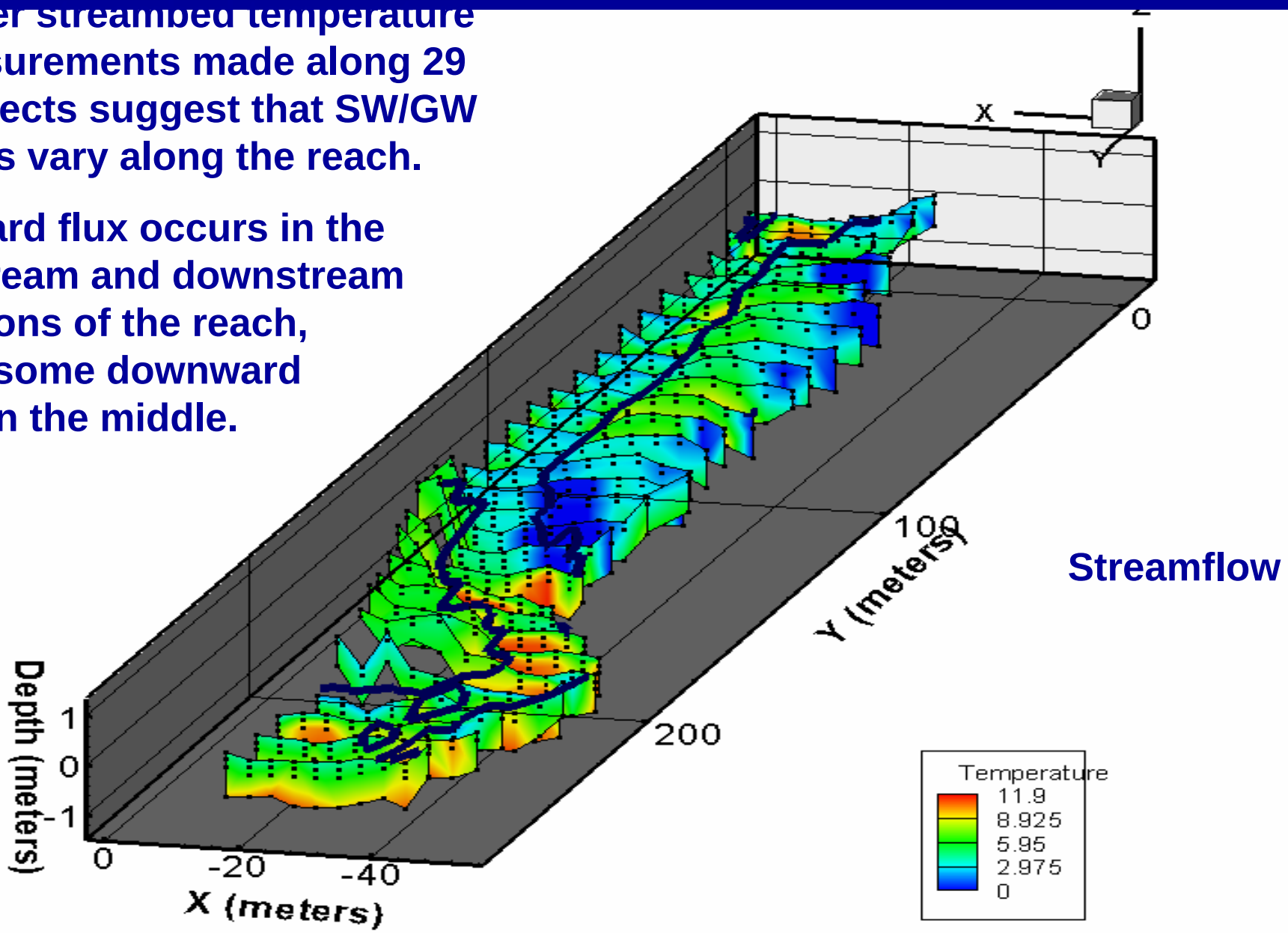
Winter streambed temperature measurements made along 29 transects suggest that SW/GW fluxes vary along the reach.

Upward flux occurs in the upstream and downstream sections of the reach, with some downward flux in the middle.



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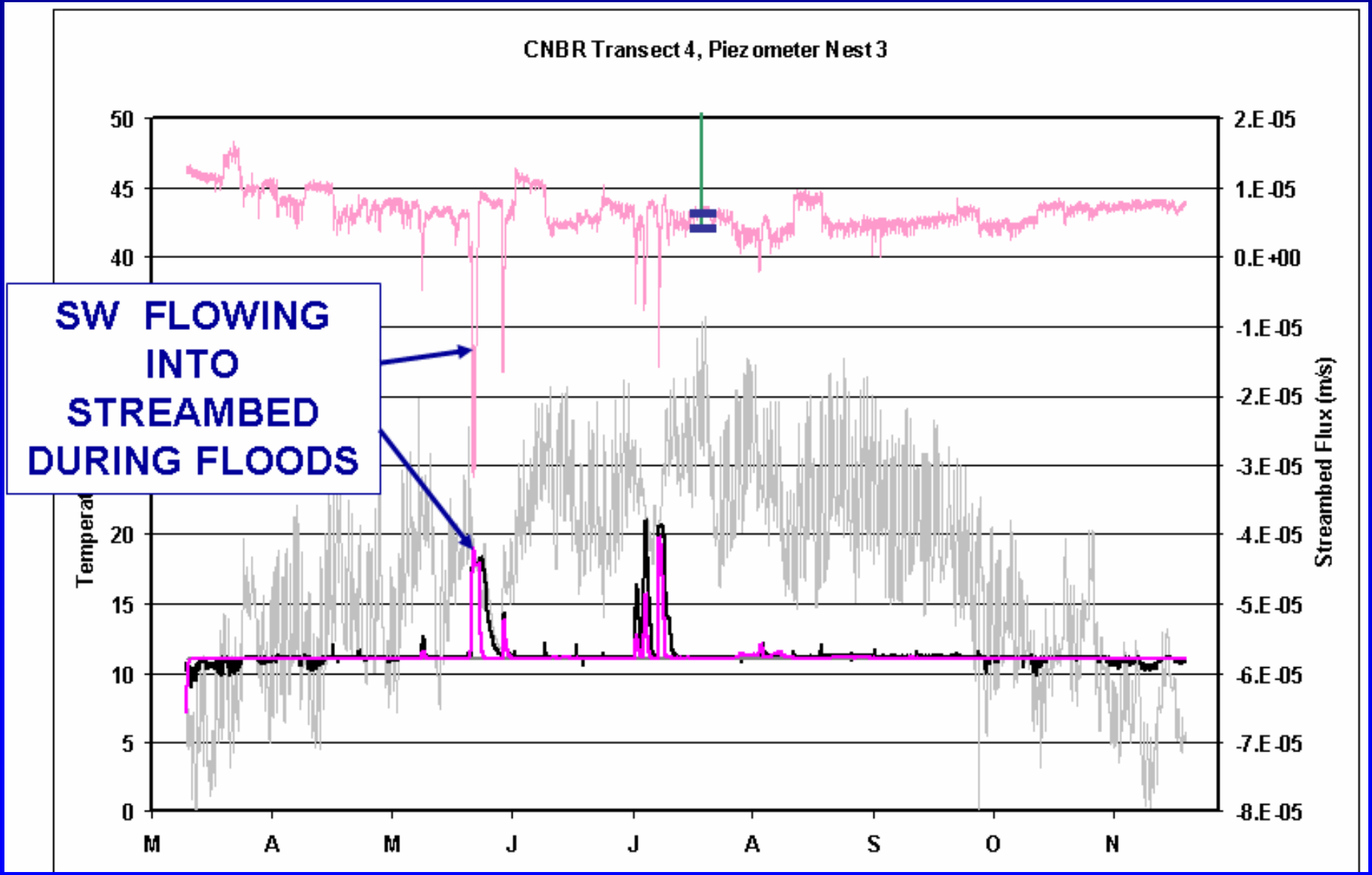

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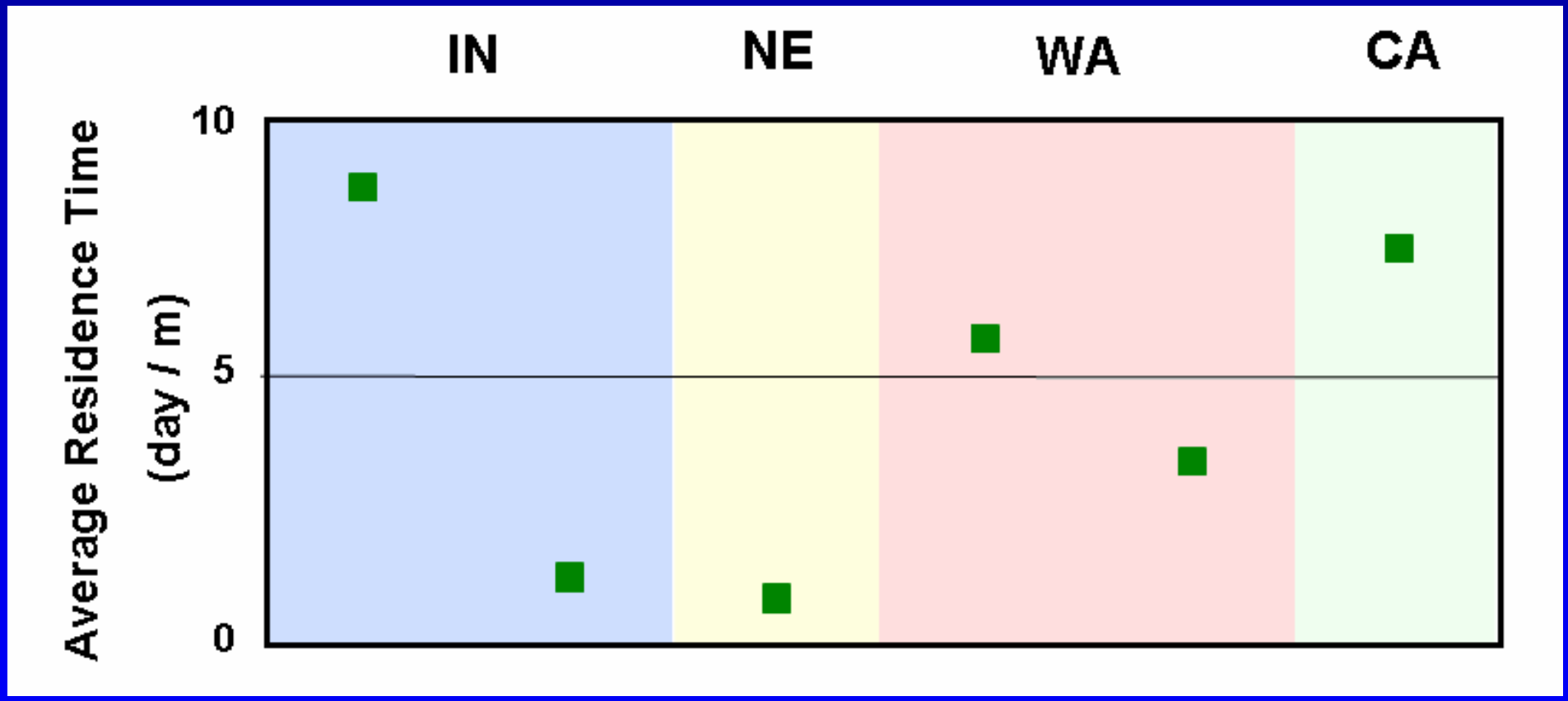
Water Residence Times in the Streambed



Longer residence time → Greater transformation

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Three Vignettes from ACT

1. Maryland: Understanding the Hydrologic System

Tracy Hancock

Mike Brayton

Leon Kaufmann

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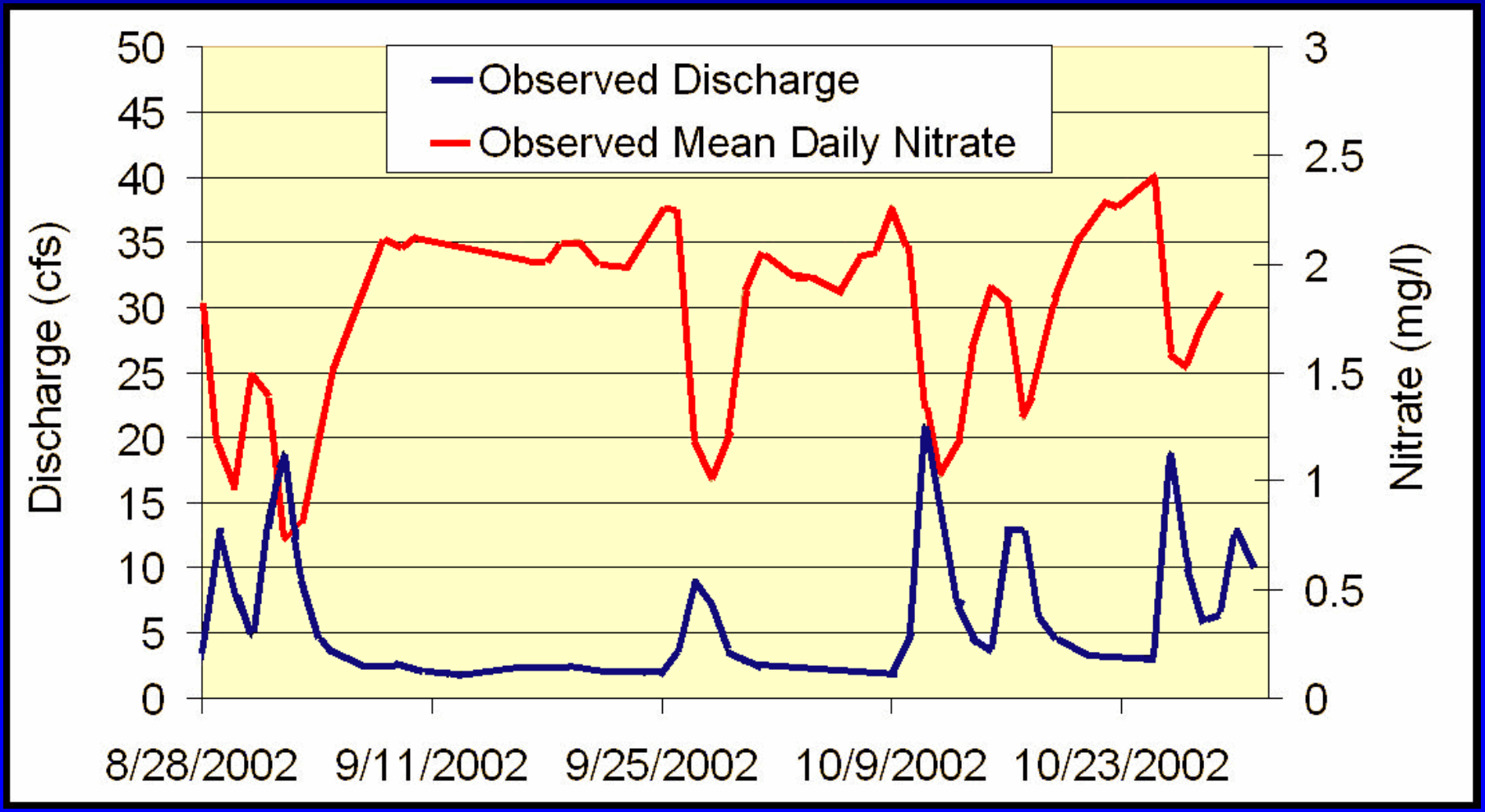
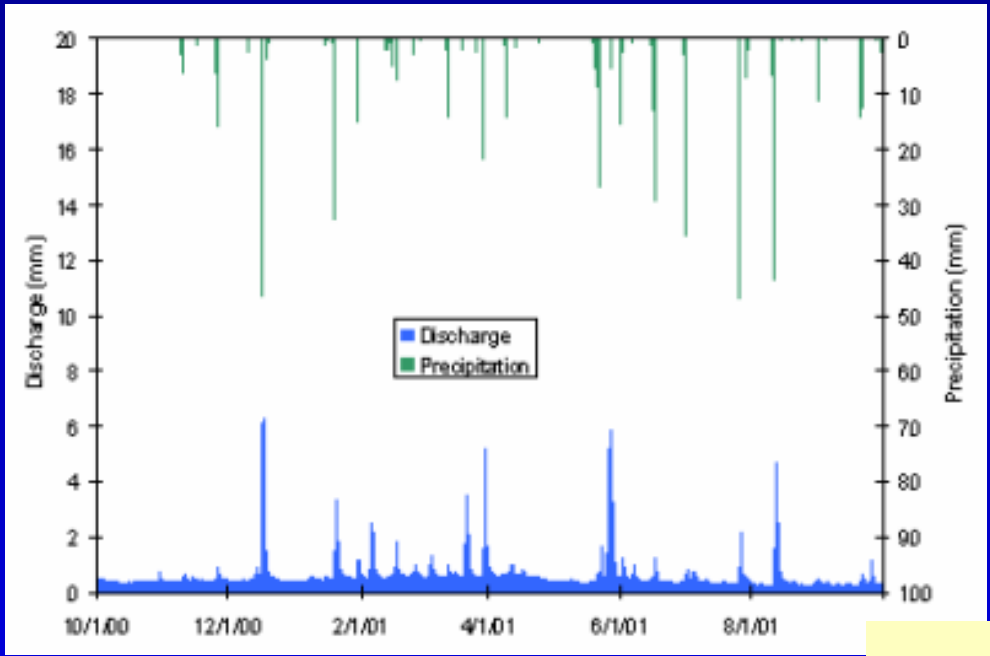
Maryland: [Nitrate] and Discharge



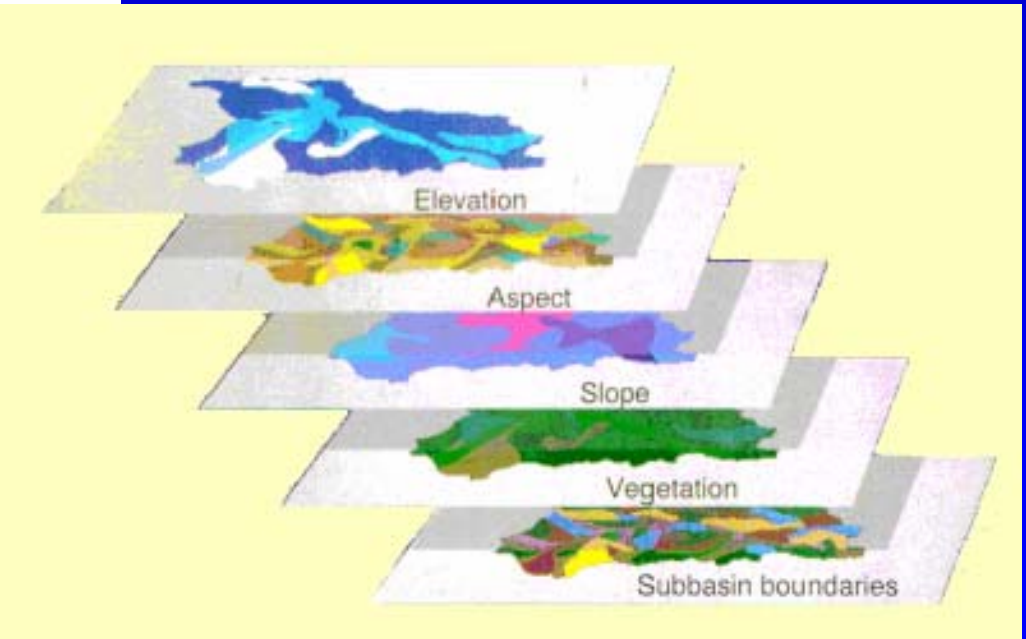
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



To understand the hydrology: both storage and transfers

^ Environmental Observations

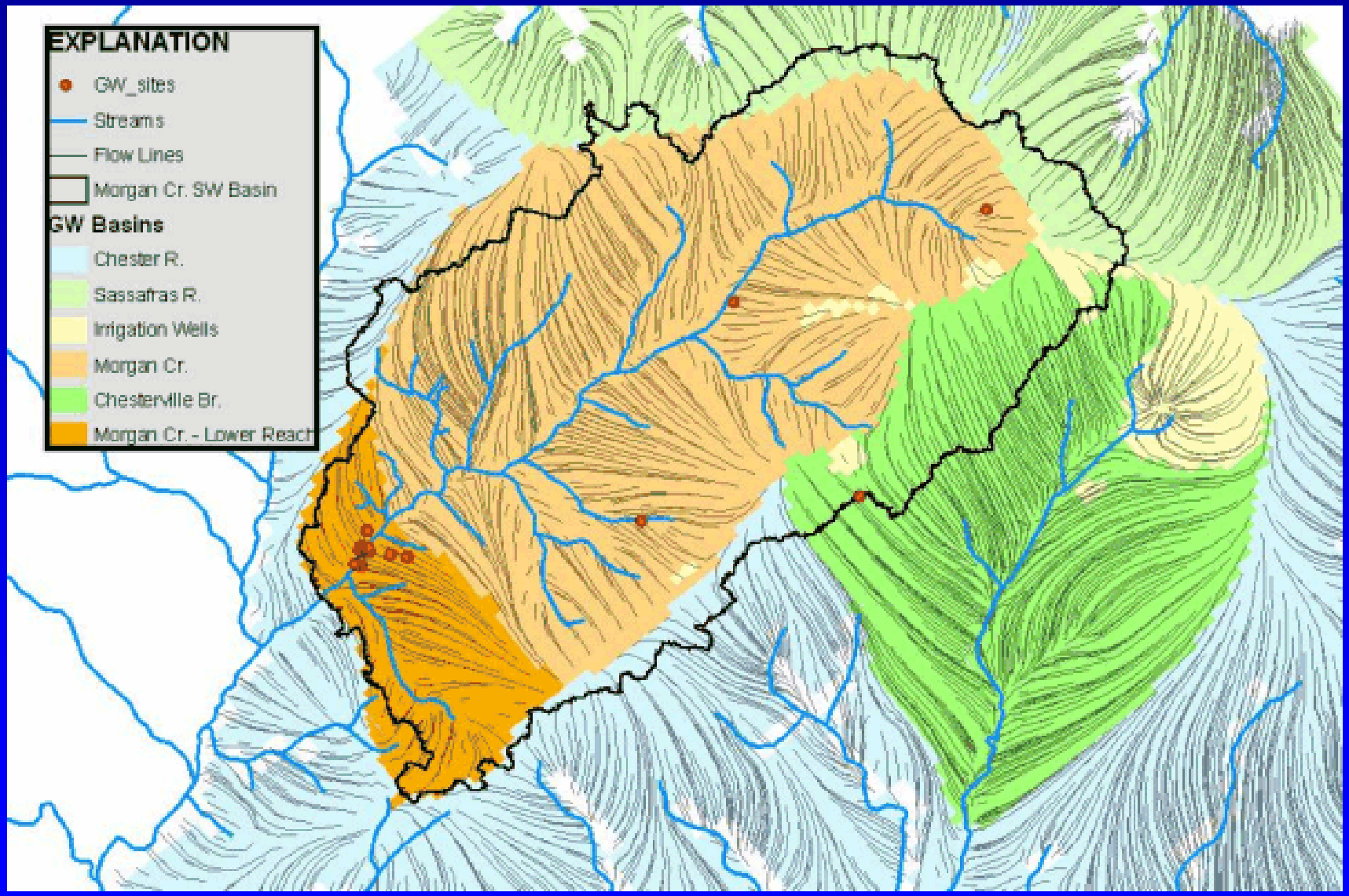
GIS Coverages + Environmental Models →



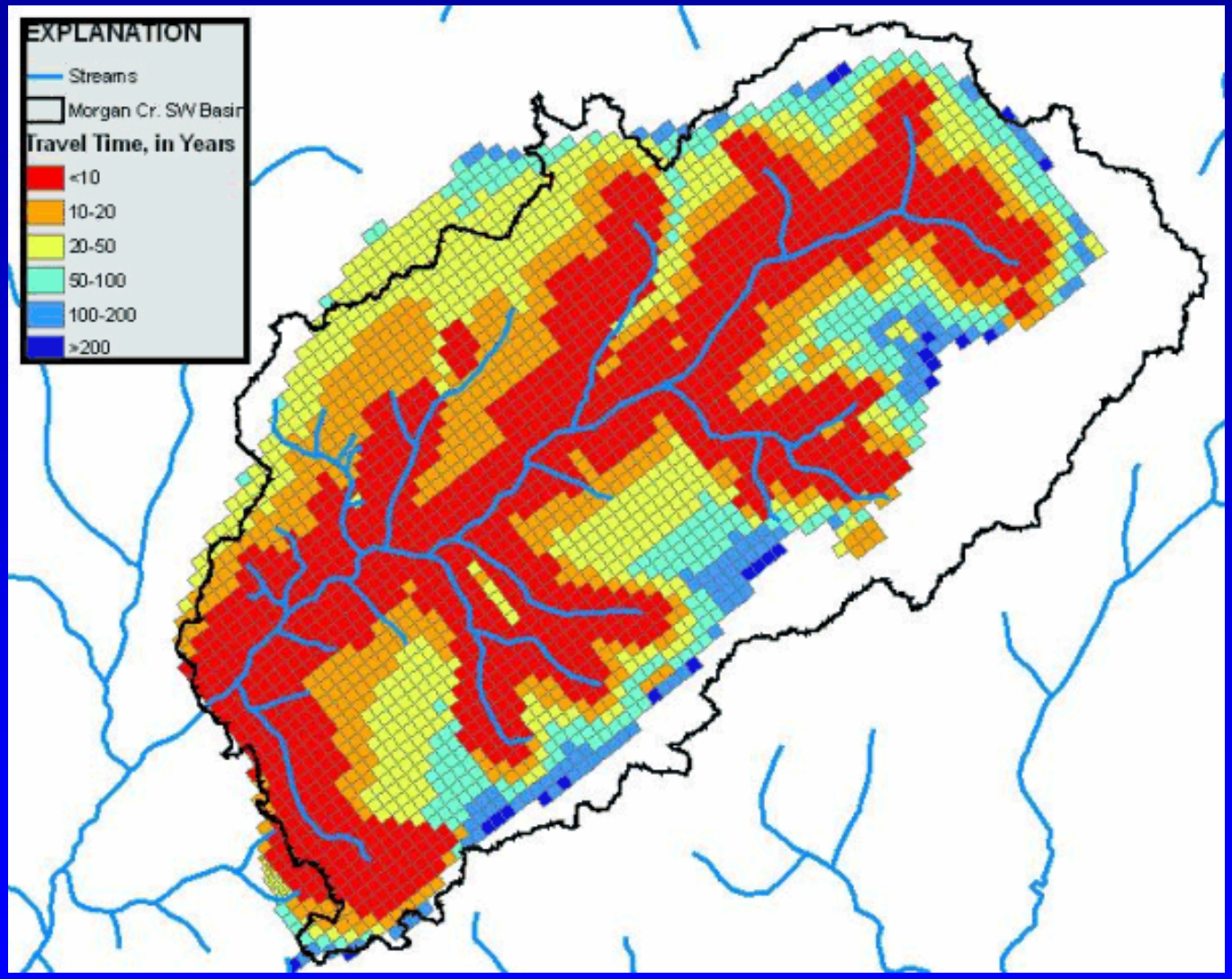
USGS

Maryland

MODFLOW: Areas contributing GW to stream

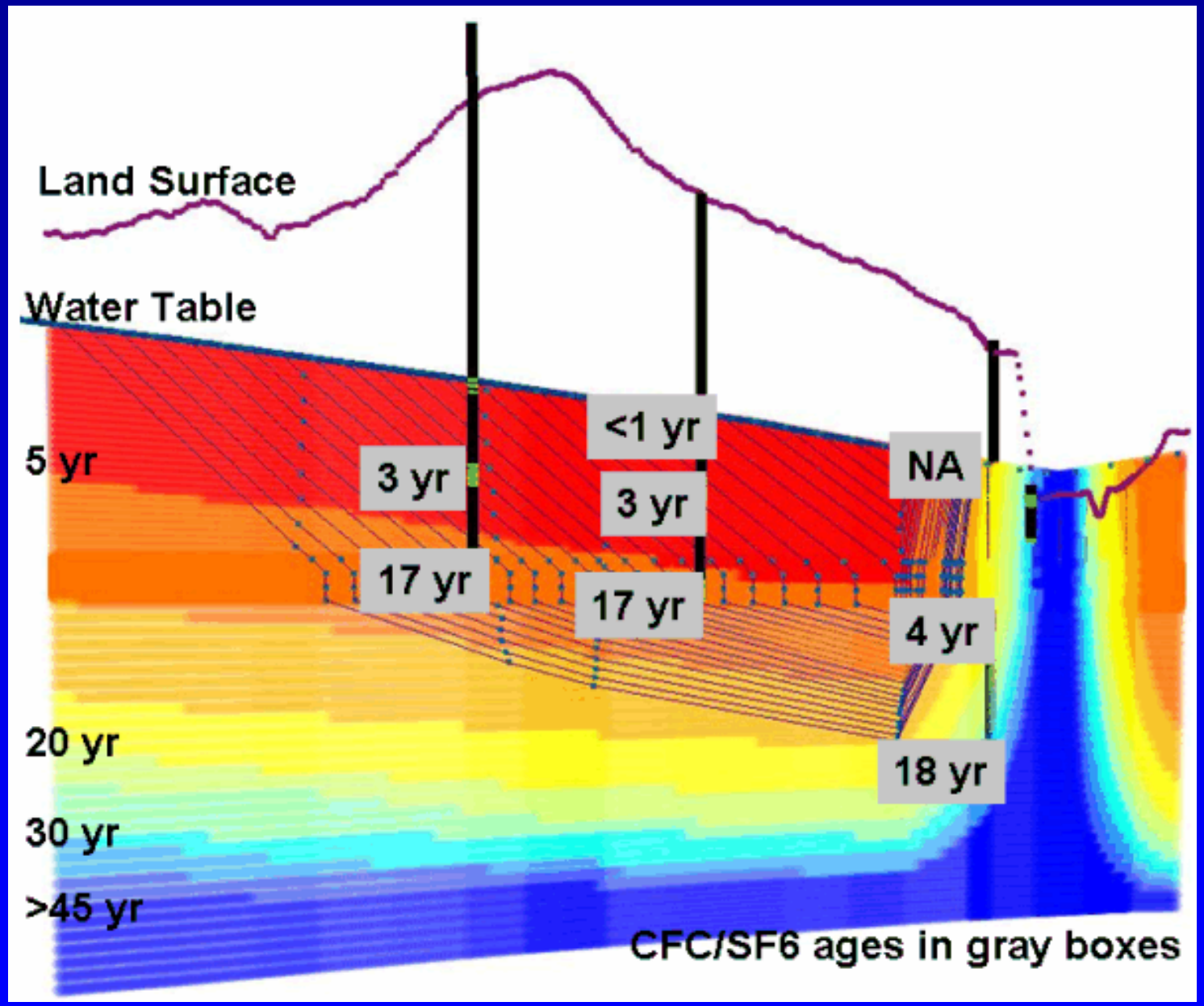


MODFLOW: GW travel times



Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

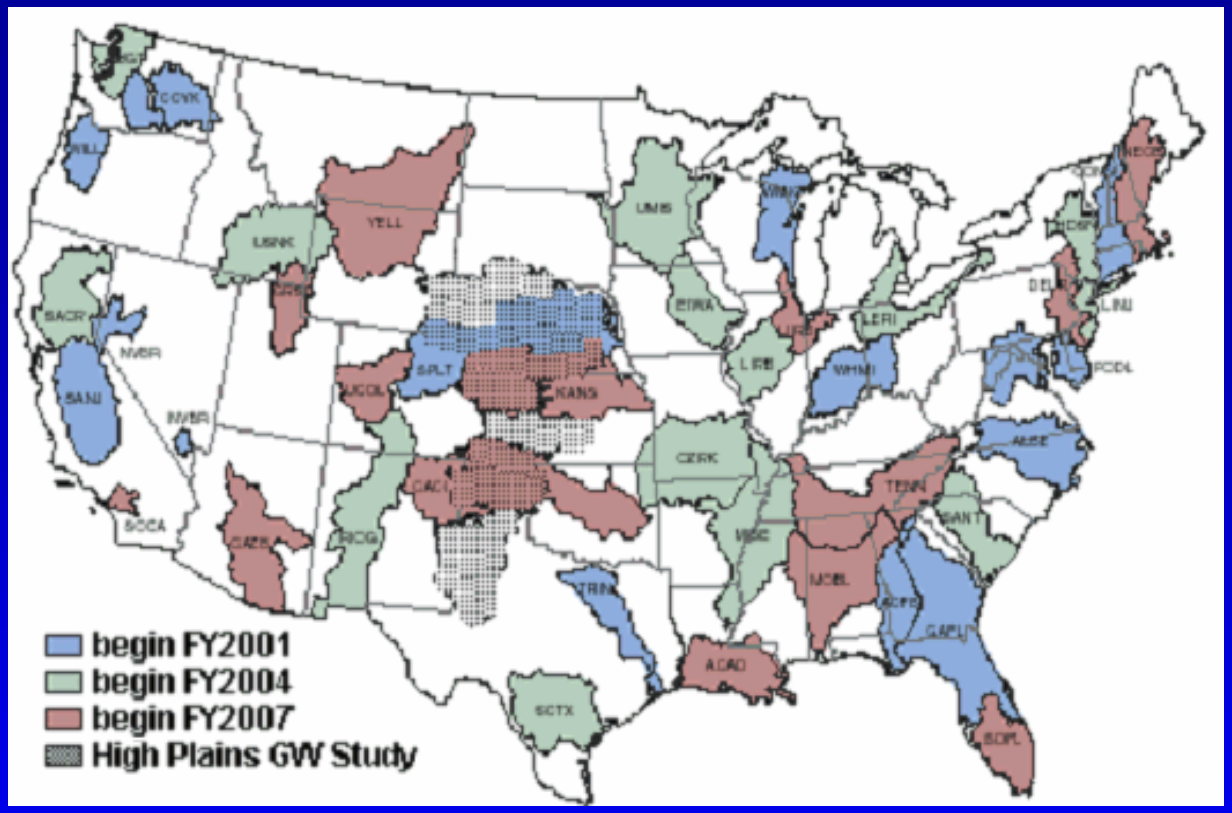
GW age for a stream cross-section



USGS

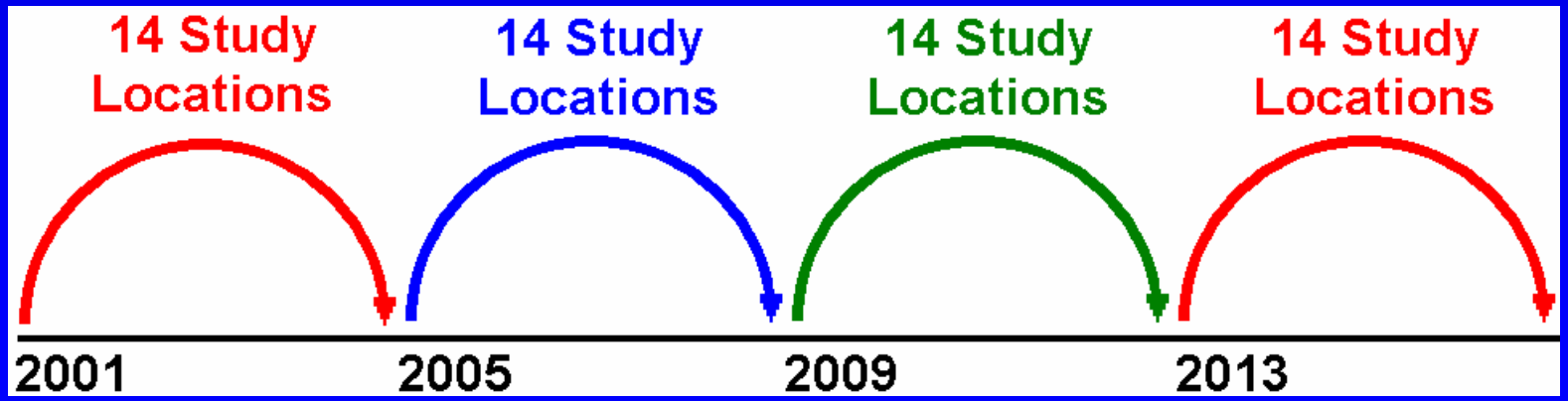
Maryland

Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



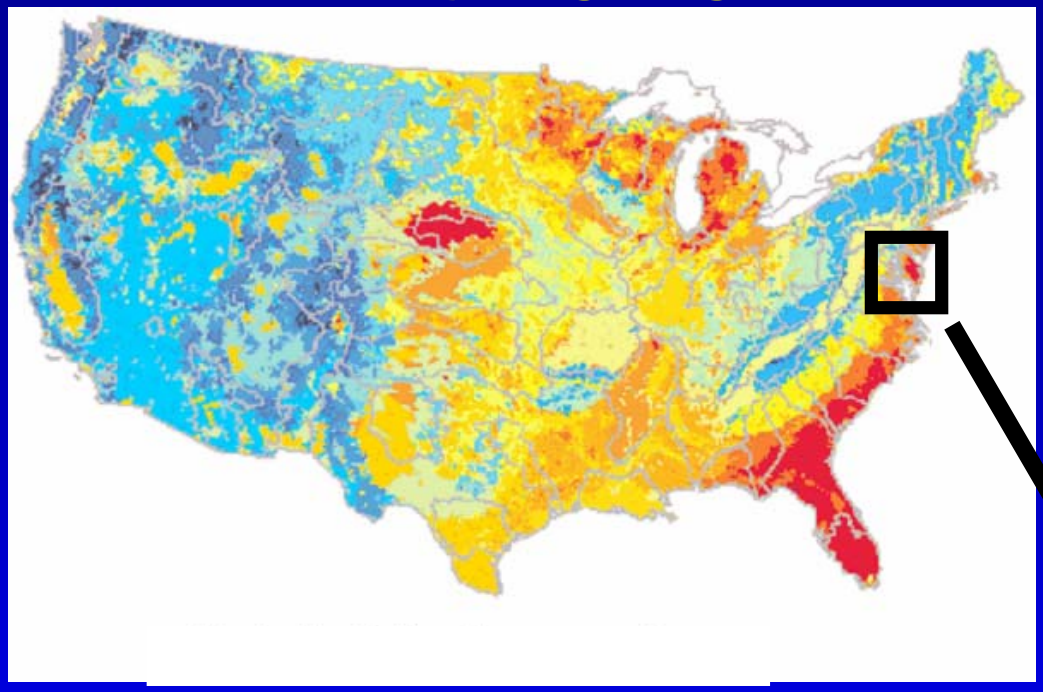
USGS NAWQA Program

Status →
Trends →
Understanding



USGS

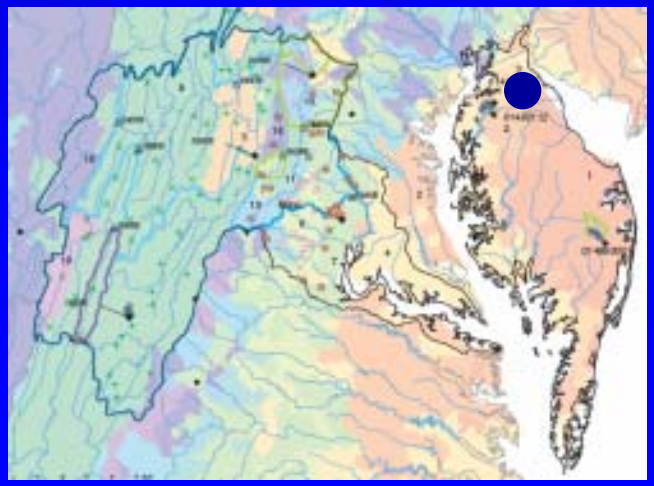
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



Hydrologic Landscape Regions

1. Land-surface form
2. Geologic texture
3. Climate

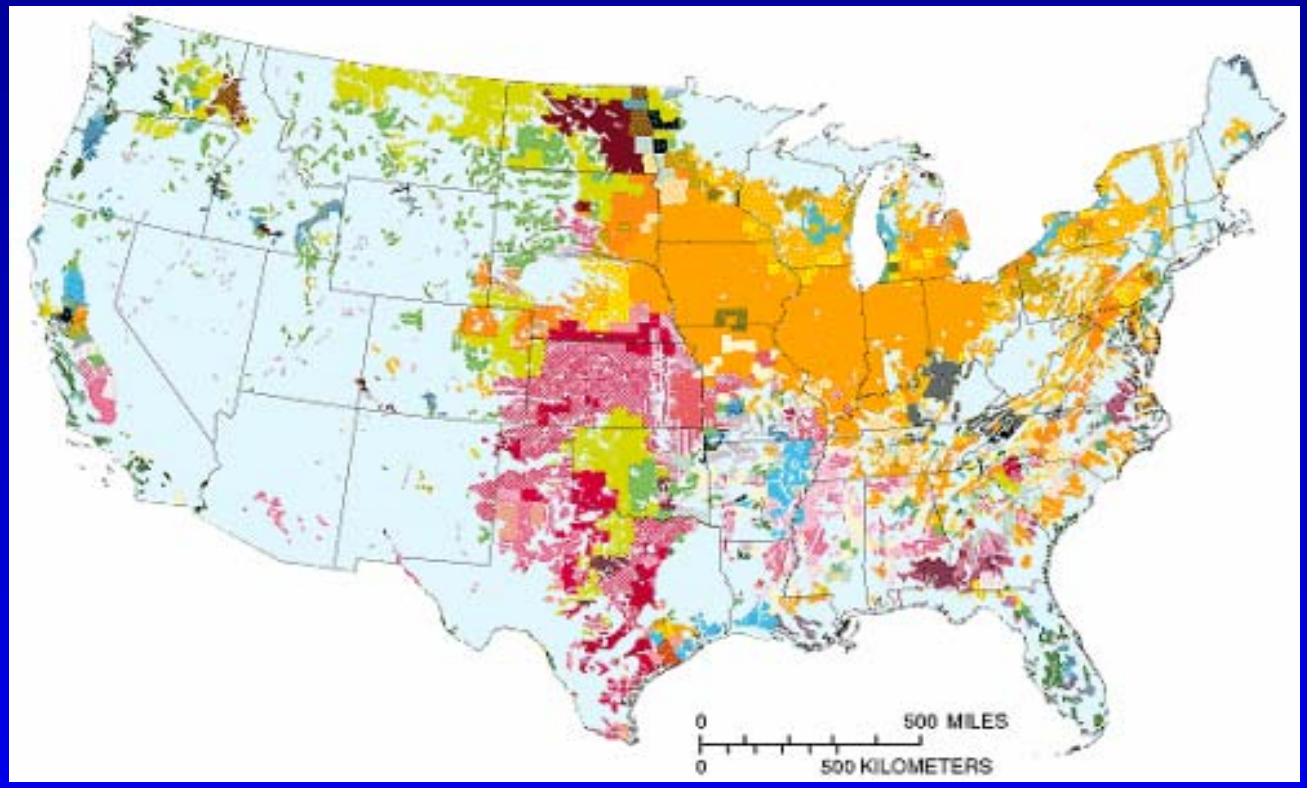
NAWQA Potomac-Delmarva Study Unit



Wet plains, highly permeable surface, moderately permeable subsurface

USGS

Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

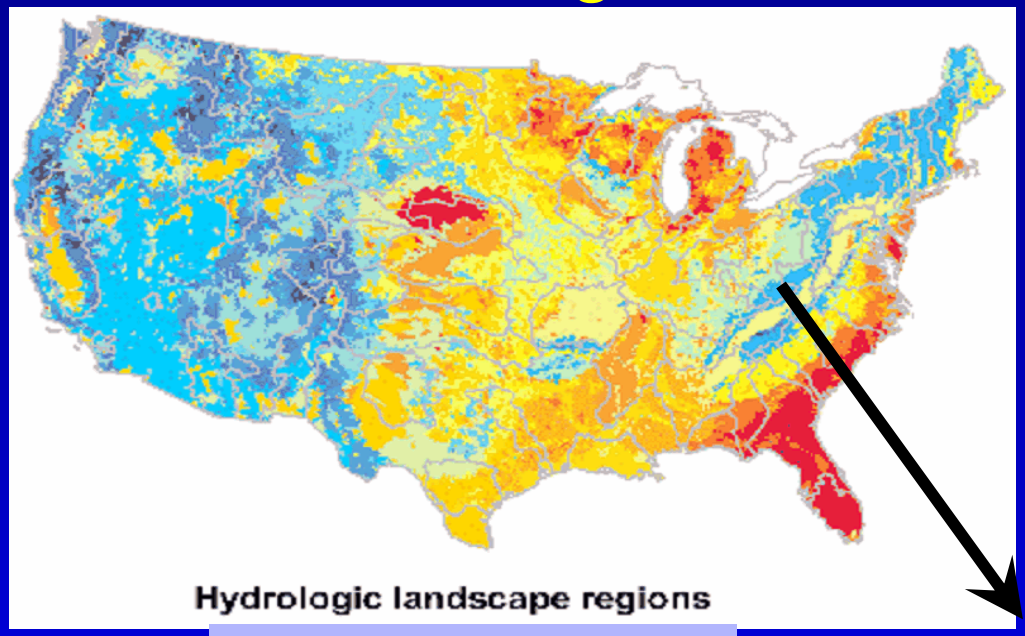


General land-use distribution USGS data (Anderson II) combined with USDA county-based agricultural census data

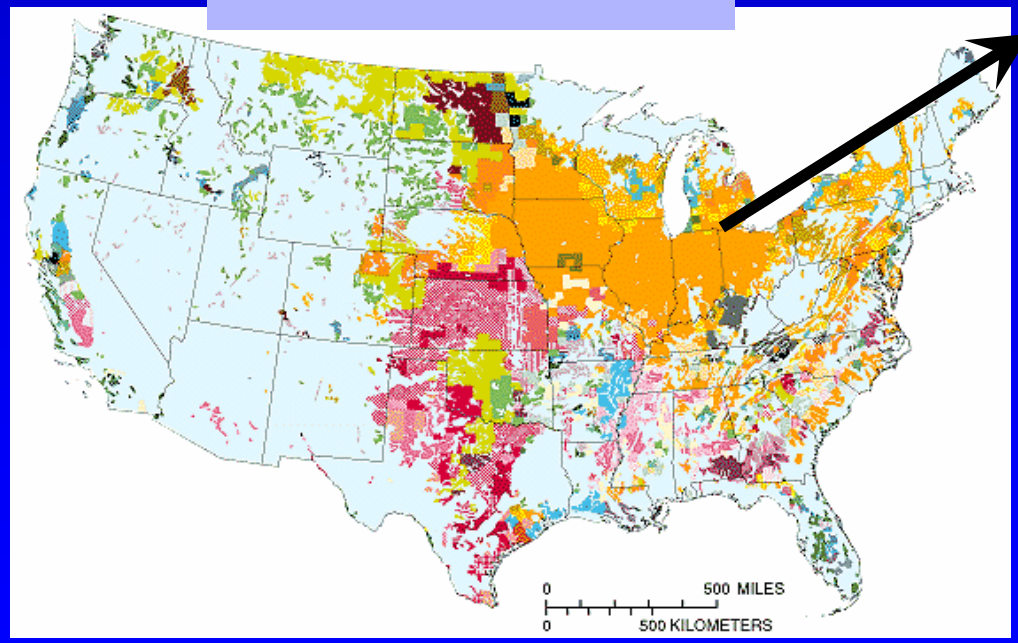
→ New classification scheme: C20S20

USGS

Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



Hydrologic settings



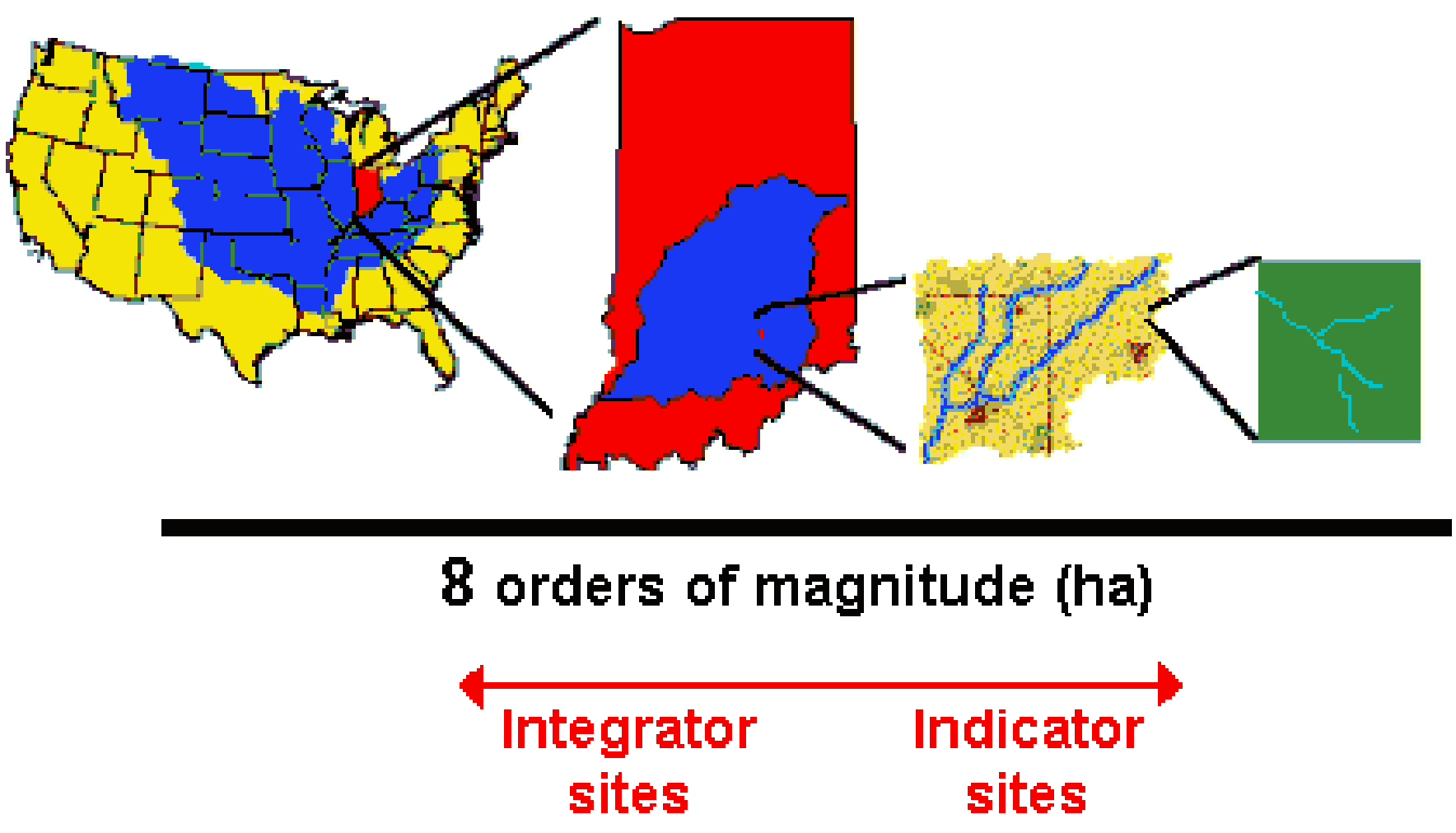
Agricultural systems

Extrapolation to Unstudied Areas

USGS

Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

Importance of Scale



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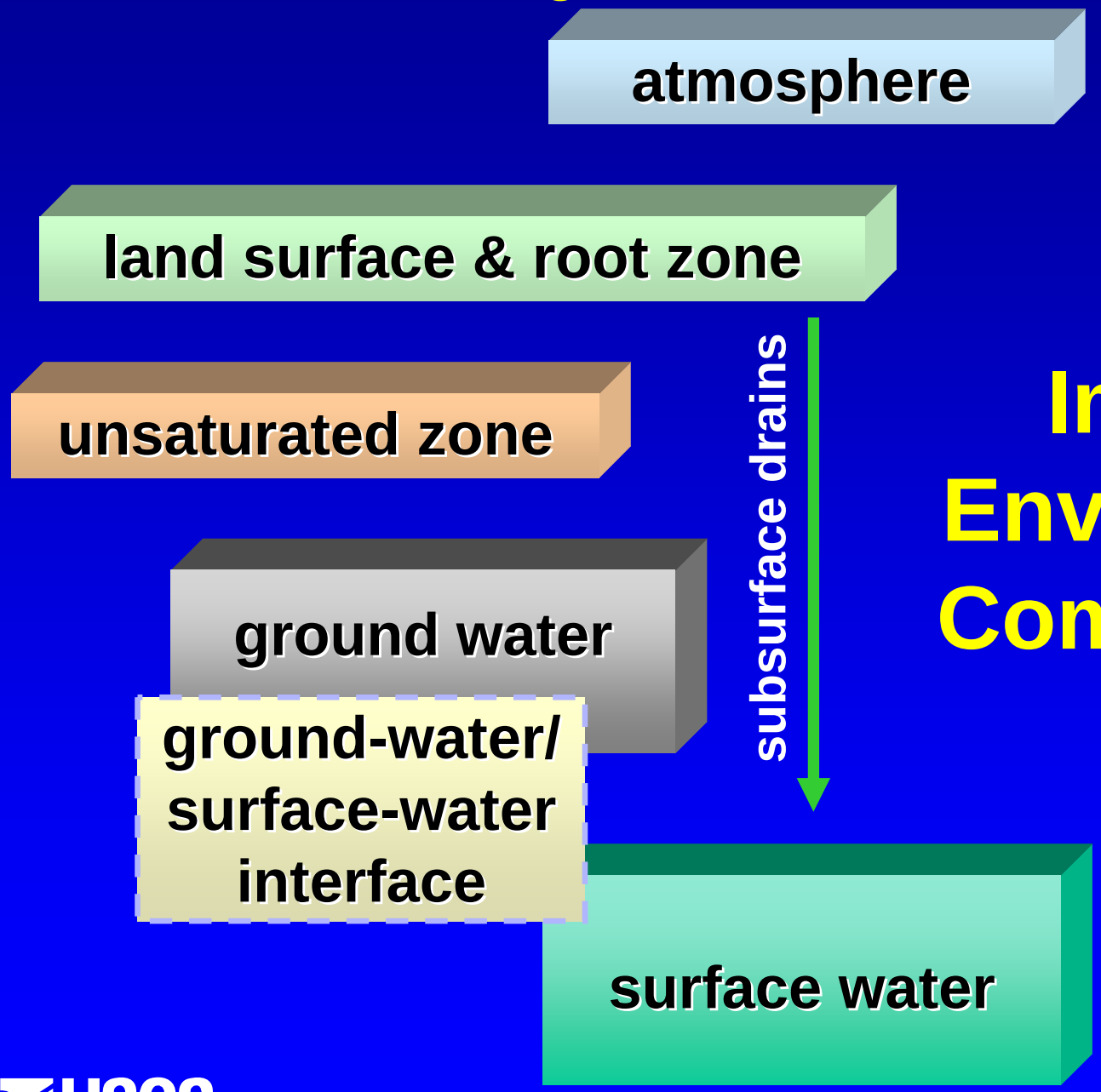
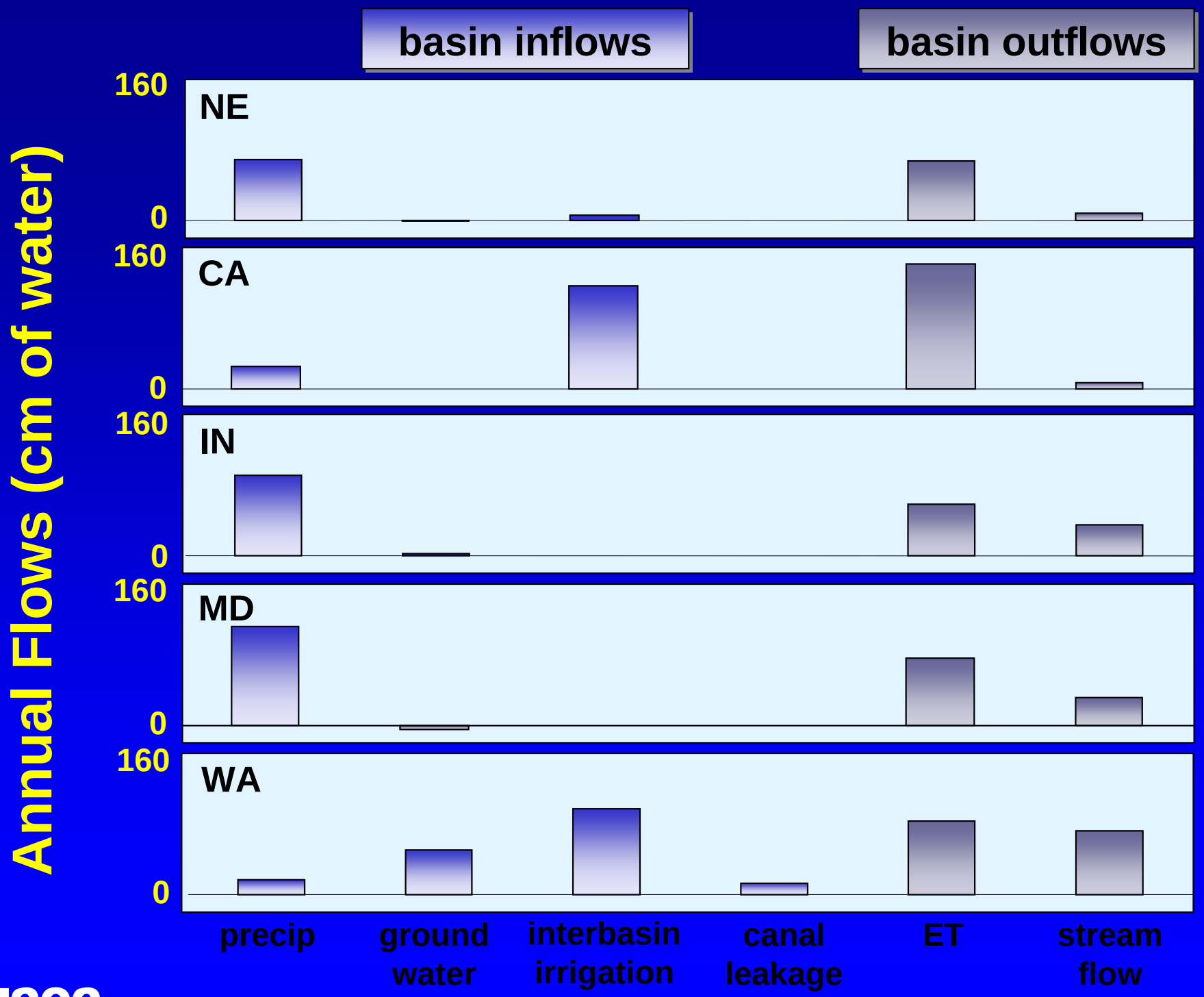
Holistic Watershed-Scale Approach for Studying Agricultural Chemicals



Important Environmental Compartments

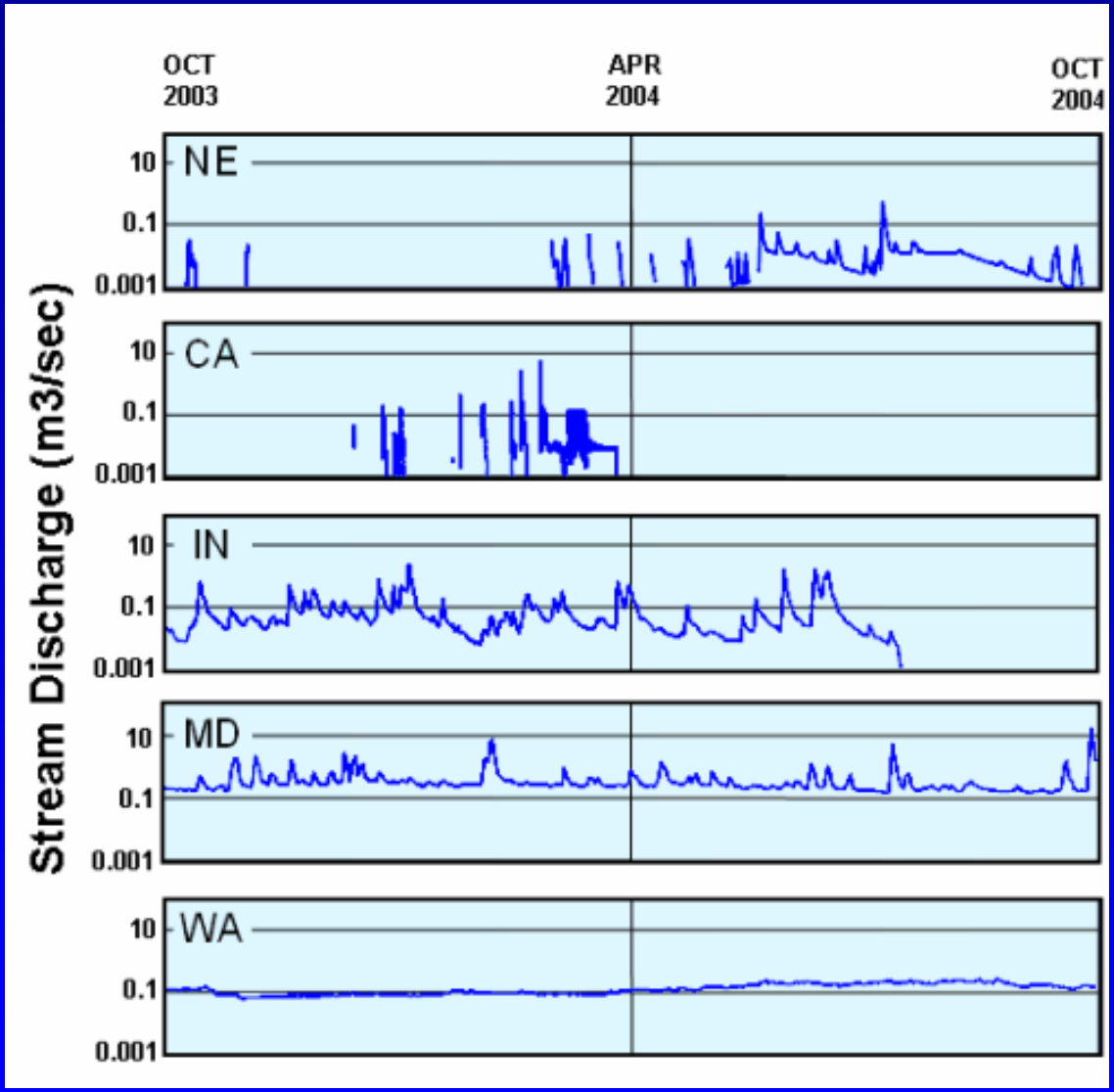
USGS


basin inflows
basin outflows
Annual Flows (cm of water)
160
0
NE
CA
IN
MD
WA
precip
ground water
interbasin irrigation
canal leakage
ET
stream flow

USGS

Holistic Watershed-Scale Approach for Studying Agricultural Chemicals

Hydrologically, the five watersheds are distinctly different !



USGS

Related Scheduled NAWQA Models:

SPARROW nutrients model for Upper Mississippi, Ohio River, and Great Lakes – scheduled 2007-08

NAWQA Reports of Interest:

Robertson, D.M., Saad, D.A., and Heisey, D.M., 2006, A regional classification scheme for estimating reference water quality in streams using land-use-adjusted spatial regression-tree analysis: Environmental Management, Vol. 37, No. 2, p. 209-229.

Robertson, D.M., and Saad, D.A., 2003, Environmental water-quality zones for streams, a regional classification scheme: Environmental Management, Vol. 31, No. 5, p. 581-602.

Robertson, D.M., Saad, D.A., and Wieben, A.M., 2001, An alternative regionalization scheme for defining nutrient criteria for rivers and streams, U.S. Geological Survey Water Resources Investigations Report 01-4073, 57 p http://wi.water.usgs.gov/pubs/wrir-01-4073/wrir-01-4073.pdf

NAWQA Reports of Interest (cont.):

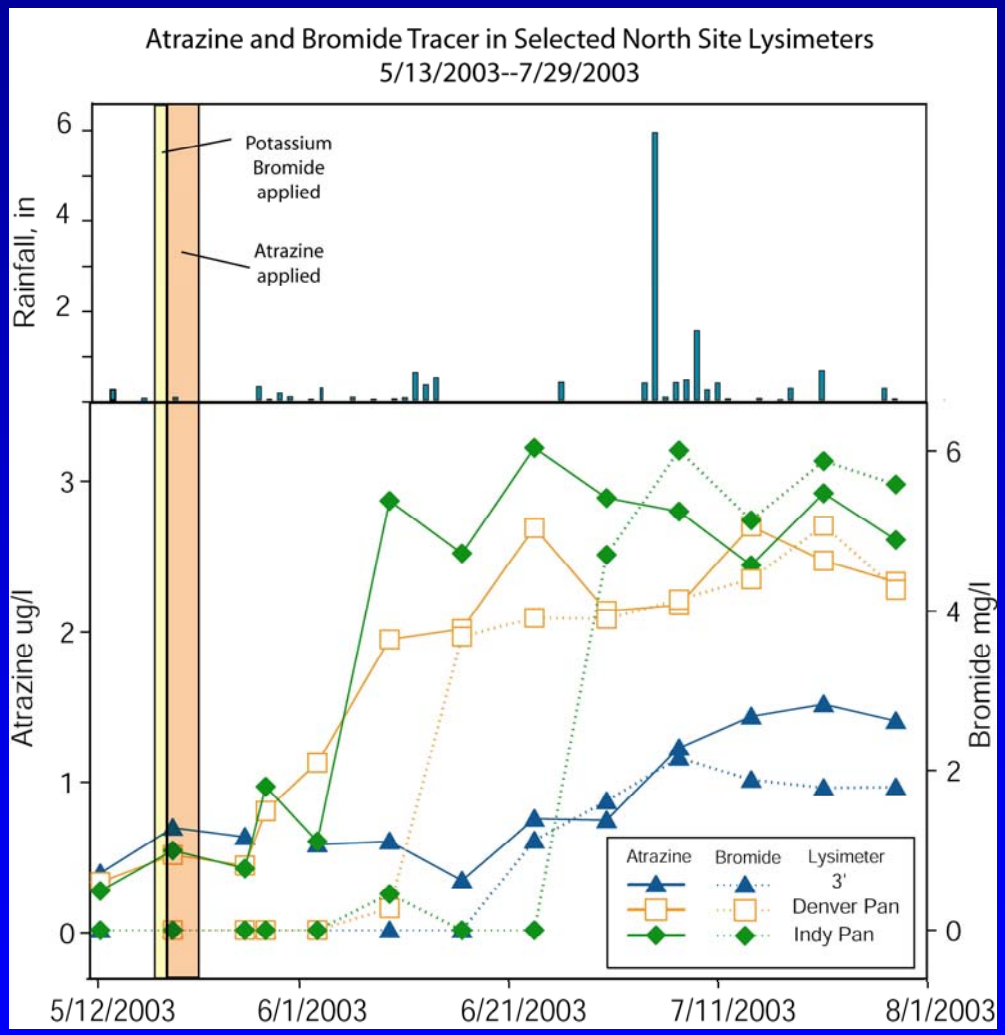
Frey. J.W., 2000, Occurrence, distribution, and loads of selected pesticides in streams in the Lake Erie-Lake St. Clair Basin, 1996-98: U.S. Geological Survey Water-Resources Investigations Report, 00-4169, 69 p.

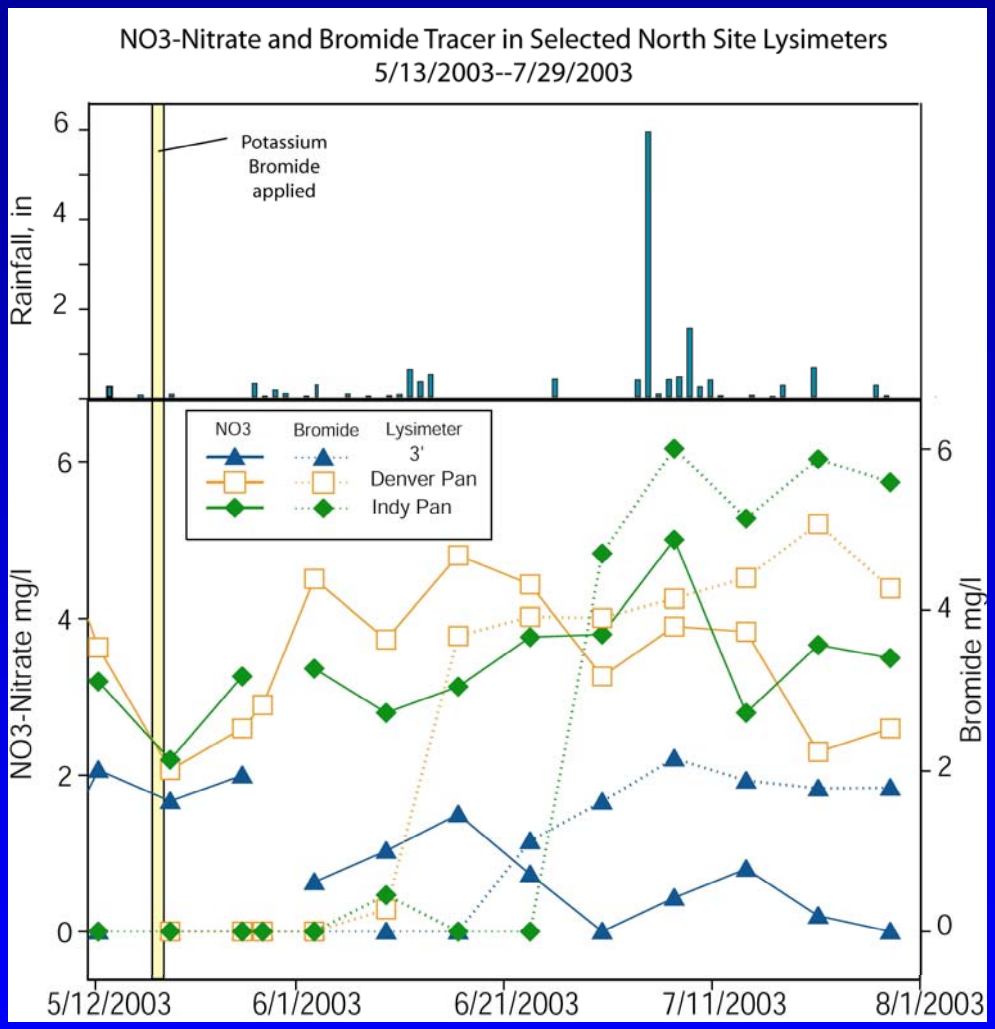
Robertson, D.M., Saad, D.A., and Heisey, D.M., 2006, Regional patterns in present and estimated reference suspended sediment concentrations and yields in streams in the Great Lakes Region and adjacent areas: U.S. Geological Survey Scientific Investigations Report: 2006–5066, 35 p. (should be on the internet shortly).

Stone, W.W., and Wilson, J.T., 2006, Preferential flow estimates to an agricultural tile drain with implications for glyphosate transport, Journal of Environmental Quality, On-line August 2006

Lorenz, D.L., Robertson, D.M., Hall, D.W., 2007, Trends in nutrient and suspended-sediment concentrations and loads in the Upper Mississippi, Ohio, Red, and Great Lakes River Basins 1975-2004, To be published as a Scientific Investigations Report.

Atrazine and Bromide Tracer in Lysimeters at the North Site

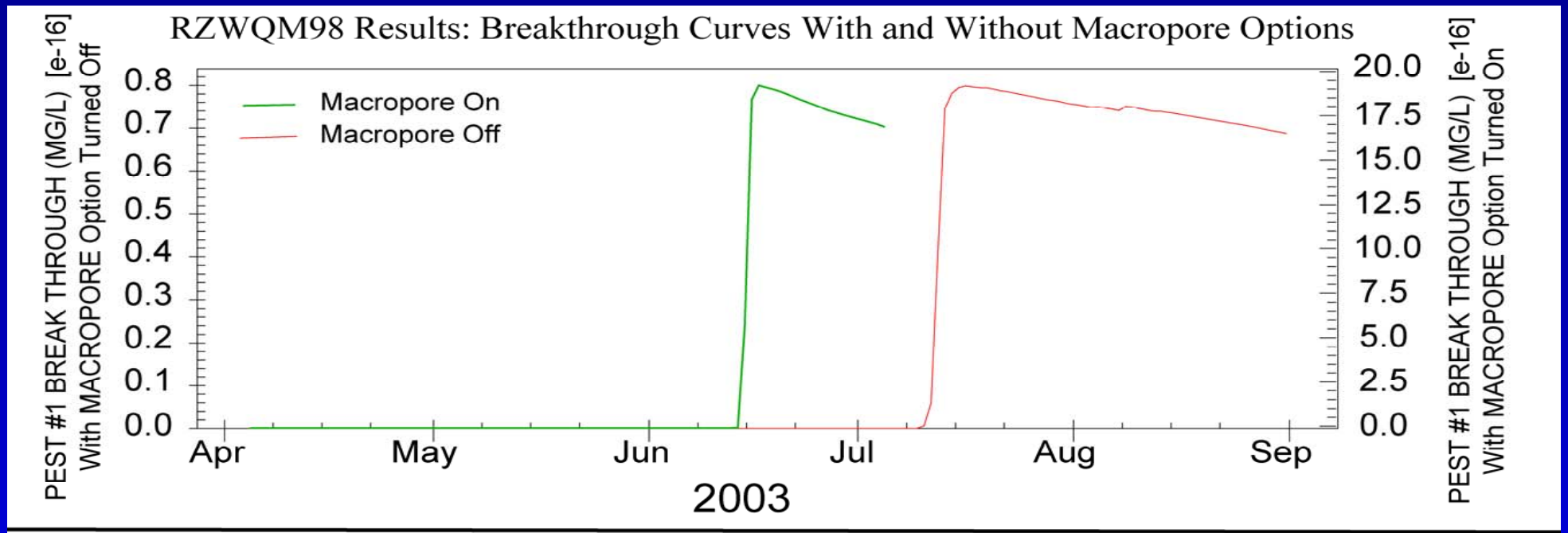


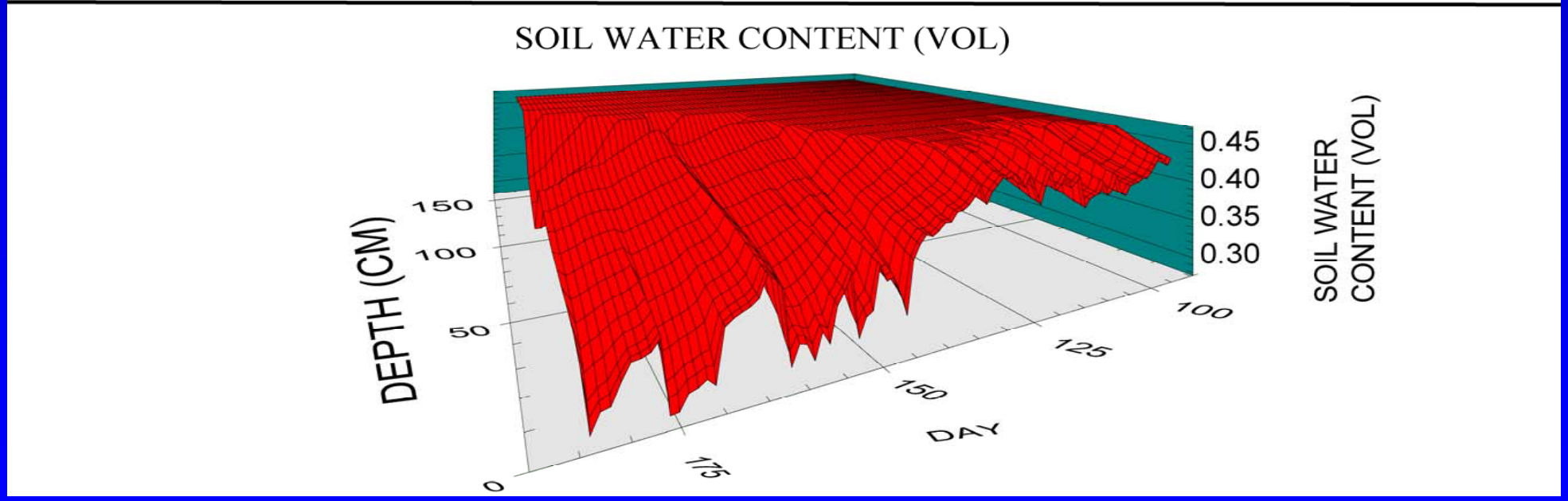


USGS

Leary Weber Ditch Study

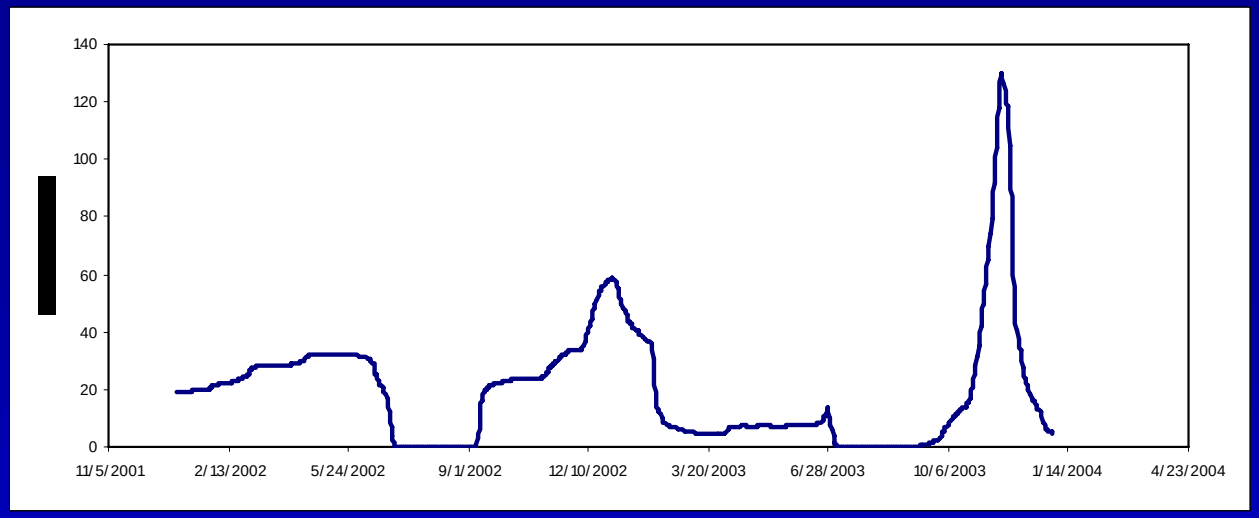
RZWQM: Preferential flow

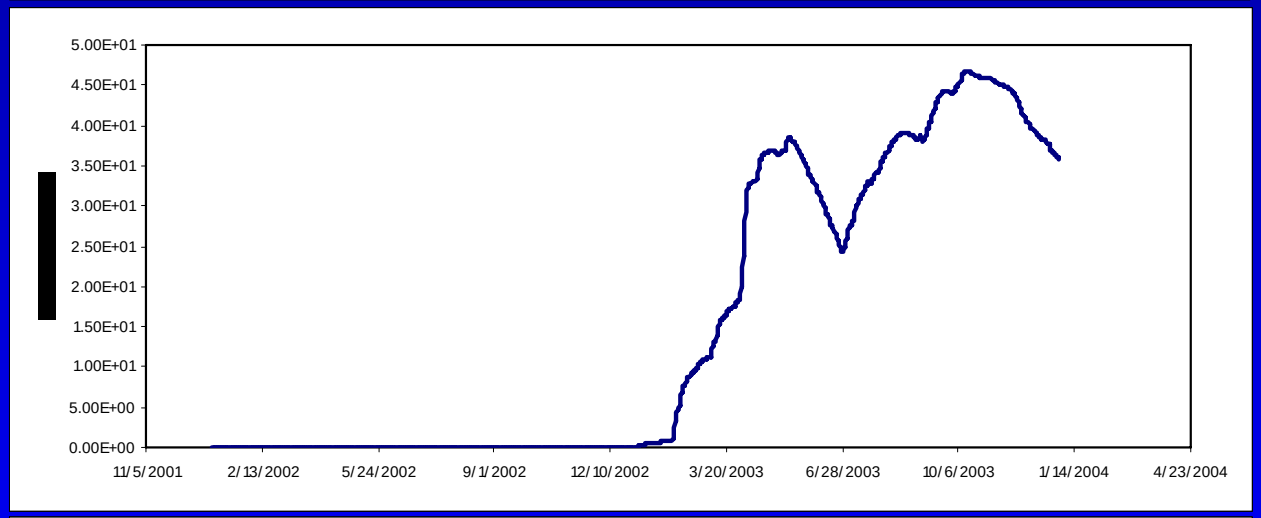


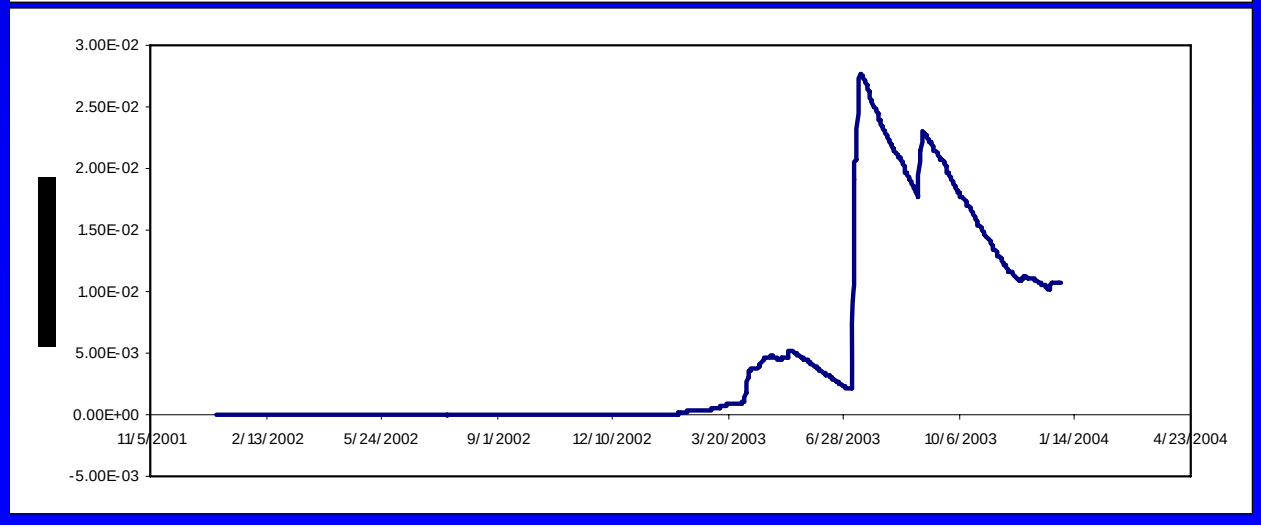


RZWQM: Breakthrough of Different Ag Chemicals:

nitrate, atrazine, glyphosate







USGS